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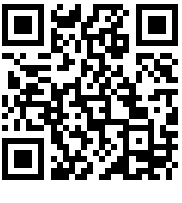

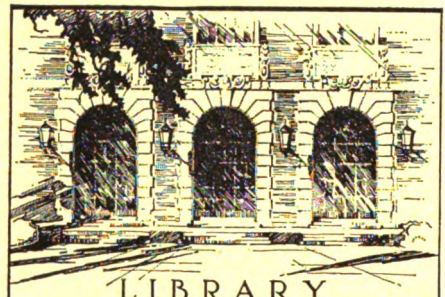

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MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1919.

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SUMMARY OF PROGRESS

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AND

MUSEUM

FOR 1919.

I.—INTRODUCTION.

By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., Director.

The expectation expressed in the Summary for 1918 that the normal work of the Geological Survey might soon be resumed was realised in 1919. A part of the series of Special Reports on the Mineral Resources of Great Britain still awaited completion, and some members of the staff were engaged upon memoirs on iron, lead, zinc, copper, arsenic and antimony, oil and salt in continuation of that series. The work, however, which had been in hand in the early stages of the war was resumed in the Denbighshire and Shropshire district (now more suitably described as the Montgomeryshire and Shropshire district), and the Warwickshire and Staffordshire district. Further work in the London and South-eastern district was postponed for the present.

In the Montgomeryshire and Shropshire district the mapping of the pre-Cambrian rocks of the Shrewsbury neighbourhood has been commenced, and that of the Ordovician has been completed so far as regards the sheets of the one-inch map in hand. A separation of the Ordovician into Caradocian and Ashgillian in accordance with the classification advocated by Prof. Marr has been adopted. The Ashgillian is difficult to distinguish from the overlying Llandovery mudstones by lithological character, but the occurrence of *Pentamerus* in the latter determines their Silurian age. The lower Llandovery beds alone appear to be present, and a gap in the sequence between them and the Tarannon is suspected. The Wenlock and Ludlow are well developed and a precise boundary might be drawn between them on palæontological evidence, but by an expenditure of time which has not been possible.

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The so-called Permian rocks between Wellington and Newport are now relegated to the Keele Beds. They appear to be faulted against the Bunter, but the boundary is obscured. The Glacial deposits are both of local and distant origin. The boulders, which include fragments of marine shells, have been derived partly from northern sources, such as the bed of the Irish Sea and the Lake District, and partly from the neighbouring parts of Wales. Expanses of Late Glacial gravels, at low levels, featureless save for recent river-bluffs, are a characteristic of the neighbourhood, as well as conspicuous developments of the hummocky form so often assumed by Glacial sands and gravels.

In the Warwickshire and Staffordshire district, the small inlier of Silurian rocks, first recognised as such by Mr. Wickham King, has been investigated. For the rest, the work lay principally in the visible coalfield of South Staffordshire and its surroundings. The selection of a line for the base of the Upper Coal Measures required much consideration, and eventually the base of the lowest coarse grit, a distinctive rock above the highest workable coal, was chosen. Good progress was made in mapping the barren upper measures, and the Triassic rocks west of the South Staffordshire Coalfield. The highly important explorations by borings and shafts to the west of the boundary-fault of the coalfield have been kept under continuous observation.

The Glacial deposits completely mask the surface and determine the nature of the soil. They consist of sands and clays with few boulders, all of western origin.

The deep borings that were being made in 1919 to prove the eastern extension of the Nottinghamshire coalfield have been systematically visited, and full particulars have been obtained.

In Scotland also the return of Geologists who had been on active service rendered some field-work possible. The Carboniferous rocks of Ayrshire and Renfrewshire in the neighbourhood of Paisley, Beith and Dunlop were revised by Mr. E. B. Bailey and Mr. J. E. Richey. Most of the district mapped consisted of lavas on the margin of the coalfields. The volcanic rocks are principally basalts of the Dalmeny, Dunsappie and Markle types, but mugearites, trachytes and keratophyres also occur. Old volcanic orifices occupied by masses of trachyte, gabbro and basalt, penetrate the lavas of the plateau; one of them is noteworthy as showing 'ring-structure.' Mr. E. M. Anderson spent a short time on the revision of the Coal Measure areas around Troon and Galston. Mr. Macgregor collected much new information from bores which are being put down in the Douglas coalfield.

In the Highlands, Mr. H. H. Read continued the revision of the Portsoy, Huntly and Insch districts of Banffshire and Aberdeenshire. In that country there is a remarkable series of plutonic igneous rocks ranging from granite to peridotite, exceptionally varied in character and presenting many interesting petrological problems. The exposures of the Highland schists, especially in the coast-section from Buckie to Gamrie, are deserving of careful study.

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Recent Borings for Oil.

The eleven borings that were being made or are in contemplation by Petroleum Development Managers, acting under His Majesty's Petroleum Executive, reached a significant stage by the close of the year. Seven are situated in Derbyshire, two in North Staffordshire and two in Scotland. The results are described on pp. 22-23, 41-43.[1] At present the Hardstoft boring has alone yielded oil in notable quantity. The amount stored at the end of 1919 amounted to 1,900 barrels.

In other borings the strata which yield oil at Hardstoft have proved unproductive.

In addition, oil has been accidentally discovered in a boring at Retford made in search of coal. It was met at a depth of 3,003 ft. in sufficient amount to justify the plugging-up of the hole with a view to conserving the oil for further investigation. Boring operations for oil at Kelham[2] had not been commenced by the end of the year.

II.—FIELD WORK.

(A)—England and Wales.

(1) Montgomeryshire and Shropshire District.

T. C. Cantrill, B.Sc., District Geologist.

B. Smith, M.A.
R. W. Pocock, B.Sc.
W. B. R. King, B.A., O.B.E. } Geologists.

During the past season the mapping of a small area between Llansantffraid-ym-Mechain and Llanfyllin in Montgomeryshire by Mr. Smith and Mr. King has completed the survey of the Oswestry Sheet (137) of the one-inch map.

In the Wem Sheet (138) a belt of country from near Ellesmere eastward to beyond Wem has been mapped by Mr. Pocock. Along the southern border of the sheet and on the northern margin of the Shrewsbury Sheet (152) the work, where suspended at the close of 1915 between Shrewsbury and Wellington, has been taken up by Mr. Cantrill, who has carried the mapping eastward as far as the eastern margins of both sheets.

PRE-CAMBRIAN.

The Uriconian rocks of Wrockwardine are found by Mr. Cantrill to consist of red and purple rhyolites, in places showing fluxion and spherulitic structures. Occasional beds of agglomerate and tuff are present, and some basic intrusions have been noted. The rocks extend under the Glacial drift as far as Admaston, where they are cut through by the Shrewsbury and Wellington railway.

[1] The history and results of the exploration are more fully set out in 'Special Reports on the Mineral Resources of Great Britain,' vol. vii, Mineral Oils, &c. *Mem. Geol. Surv.*, 2nd ed., in the press.

[2] Near the site of the boring described in the 'Summary of Progress for 1917,' *Mem. Geol. Surv.*, 1918, pp. 48–50.

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ORDOVICIAN.

The subdivision of the Bala beds into two stages, viz., Caradocian and Ashgillian, as mentioned in the *Summary* for 1915 (p. 5), has been applied by Mr. King in the Llanfyllin area.

The Caradocian stage consists of sandy mudstones with fine-grained muddy sandstones, one of which, a ripple-marked band somewhere near the middle of the stage, attains a thickness of 10 ft.

The lower portion of the stage is rather poor in organic remains, but in the higher beds fossils became more abundant. These generally consist of brachiopods (*Orthis elegantula* and *O. alternata*), trilobites (*Asaphus*, *Calymene*, and *Trinucleus* of the *concentricus* type) and lamellibranchs.

Near the top of the stage the beds become more calcareous, and lenticular bands of limestone come in, while the arenaceous beds appear to grow ashy. In a few localities where the beds are well exposed (*e.g.*, at Lluest quarry, a mile south of Llanfyllin), thin bands made of fragments of felspars, etc., are to be seen interbedded with the sandy ash-beds and lenticular limestones. These beds contain fossils that resemble those in the sandy mudstones below, although in the quarries at Bwlch-y-cibau certain bands are crowded with large beautifully-preserved specimens of *Strophomena*, which are less abundant in the lower beds.

In the area south and south-east of Llansantffraid-ym-Mechain, mapped by Mr. Smith, the higher part of the Caradocian consists of sandstones and shales with poor cleavage, overlain by black shales with thin bands of limestone.

The sandstone group, where typically developed, consists of tough blue micaceous and laminated sandstones or fine grits, up to 1 ft. in thickness, with interbedded thin shales and sandy mudstones, the softer beds being cleaved. They are characterised in this area by the inclusion of some beds of rather platy fine-grained sandstone of a compact silty nature, traversed by narrowly-spaced strike-joints at right-angles to the bedding. In some of the slightly calcareous beds fossils characteristic of the Caradocian are abundant.

The fine ash and lenticular limestones of the Llanfyllin district pass up into massive grey rather impure limestones. These are well exposed in the Lluest dingle, and appear to be identical with those to be seen in the quarry at Pen-y-garnedd, and which we propose to call the Pen-y-garnedd Limestone. At Bwlch-y-cibau the limestone is reported to have been burnt for lime, and both here and at the quarry near Greenhall these strata contain *Orthis actoniae*.

The phosphate-bed that occurs between the limestone and the overlying graptolitic black shales is not now exposed, although an adit near Greenhall quarry is said to have reached it. At several localities the black shales have yielded graptolites, generally in poor condition except at Pen-y-garnedd quarry, where the section has been opened up and cleared during the war. Some well-preserved specimens collected here have been identified by Miss

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G. L. Elles, D.Sc., F.G.S., who visited the more important sections of the limestone and shales. They[1] prove to be various species of *Orthograptus*. The exact horizon of these shales has, however, not yet been definitely fixed; but from a preliminary study of the graptolites Miss Elles assigns them to the *Diplograptus pristis* zone of Sweden, which is correlated with the highest Caradocian of Britain. The shales, therefore, are a graptolitic facies of a part of the sequence usually represented in this country either by calcareous or arenaceous beds (as at Bala and in Carmarthenshire and Shropshire), or by barren mudstones (as in the Southern Uplands of Scotland).

South and south-east of Llansantffraid the Caradocian beds mapped by Mr. Smith are surmounted by the Pen-y-garnedd black shale group, which has a thickness ranging up to about 100 ft. The shales contain thin bands of crinoidal limestone, the thickest seen measuring no more than a few inches.

In the shales small brachiopods, but no graptolites, have been discovered. They are exposed in a wood (where they are said to have been dug formerly in search of coal) about 400 yards E.S.E. of Vyrnwy Bank Farm, 1½ miles E.N.E. of Llansantffraid. Other exposures occur at Dingle, about half a-mile farther south. The beds appear to be referable to much the same horizon as the Gwern-y-brain group[2] of the Welshpool District.

The realization on more detailed mapping that the black shales may replace part or nearly the whole of the limestone-group enables us to account for their varying thickness, which was formerly[3] attributed to unconformity between the Caradocian and the Ashgillian stages. This appearance of discordance seems also to have been due at some localities to strike-faulting, which would naturally follow the strike of the soft shales. In no exposure has the Ashgillian been seen to be unconformable to the black shales.

The Ashgillian strata in Mr. King's district near Llanfyllin consist in their lower part of soft green-grey mudstones, with spots and blotches of a darker blue-grey colour. Bedding is not well developed, although, in a few places near the base, nodules, presumably rather more calcareous than the rest of the rocks, are present along bedding-planes. The fossil-contents consist mainly of trilobites and small brachiopods of the species usually met with in the lower part of the Ashgillian in Wales.

The middle and upper parts of the Ashgillian stage tend to become gradually more sandy, although the grains of sand are always extremely fine. Towards the top of the stage, thin siliceous bands come in, and the strata, although retaining their grey-green colour, grow more shaly and sandy, and less like mudstones. The beds are fossiliferous throughout; but it is only in certain bands in the middle and upper portions that fossils occur in any abundance.

[1] Previously some poor specimens had been identified as *Mesograptus multidens*. 'Summary of Progress for 1915,' p. 5.

[2] A. Wade, 'The Llandovery and Associated Rocks of North-Eastern Montgomeryshire,' *Quart. Journ. Geol. Soc.*, vol. lxvii, 1911, pp. 428–431.

[3] 'Summary of Progress for 1915,' p. 5.

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South of Llansantffraid, in the ground mapped by Mr. Smith, the Ashgillian Beds occupy the centre of a broad synclinorium of folded Caradocian Beds, its central axis lying slightly oblique to the course of the river Vyrnwy.

The strata consist chiefly of greyish-green or blue to brown mudstones, occasionally with sandy lamellæ. Some of the beds are spotted and blotched by little inclusions of a dark-blue tint, recalling the speckled Llandovery beds of the Mynydd-Cricor and Glyn districts in the Llangollen area. In places they are calcareous and contain sandy and calcareous nodules arranged along the dip, with their flat sides at right angles to the bedding. The calcareous nodules occasionally resemble smooth cement-stones, and may form thin beds of limestone. These rocks are richly fossiliferous.

They are overlain by a belt of thin limestones with inter-bedded ashy shales, well exposed in a quarry 200 yards N.N.W. of Gelli Farm (1 mile S.E. of Llansantffraid), and again in the dingle south-east of Trewylan House, to which position they are thrown southward by a transverse fault. The limestones contain many fine corals. These beds have not been recognised elsewhere within the area covered by the map.

Above the coral limestones the Ashgillian Beds are in the main fossiliferous nodular mudstones, but contain arenaceous matter in the form of thin tough blue laminated sandstones.

SILURIAN.

The detailed mapping of the main mass of Silurian rocks of the Llanfyllin area by Mr. King has led to the discovery of both Llandovery and Tarannon rocks between the Ashgillian and the Wenlock.

The exact base of the Llandovery is usually difficult to determine. This is largely due to the fact that the Ashgillian tends to become more sandy in the higher parts while the lower parts of the Llandovery, though mainly mudstones, contain sandy or siliceous beds. Certain beds presumably near the base of the Llandovery contain bands of calcareous matter. The mudstone of these strata is as a rule rather more blue than that of the Ashgillian. Fossils are scarce, but specimens of *Pentamerus* have been found, which leaves no doubt as to the Silurian age of the beds. Moreover, beds with *P. undatus*, etc., have been found at Pen-y-godor near the River Vyrnwy, in a syncline on the southern margin of the one-inch sheet.

In the extreme south of the sheet, on Allt-gôch, a massive fine-grained grit with basal conglomerate rests on the Ashgillian beds. The grit itself is some 15 ft. thick, and is non-fossiliferous; but the basal conglomerate, which runs up to 2 ft. in thickness, contains numerous fossils. Most of these appear to be small corals, although a few brachiopods also have been found. The majority of the pebbles in the conglomerate consist of vein quartz and fine-grained igneous rocks.

In the Glyn-Ceiriog valley the Glyn Grit was assigned to the Ordovician; but although the grit of Allt-gôch appears to come in at about the same horizon, the field-evidence, as far as it

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goes, tends to place this grit in the Silurian. The matter will probably be settled when the fossil-evidence has been thoroughly worked out. The grit can be traced northwards to near Pant, a distance of about a mile, where it suddenly disappears.

A soft but massive sandstone, 6 to 10 ft. thick, crops out near Rhôs-fawr, on the western edge of the one-inch sheet, and again on Craig-fawr, still farther west, where it has yielded traces of fossils. As these are indefinite, the position of this sandstone in the sequence remains undetermined.

From the fossil-evidence the Lower Llandovery alone seems to be present in this area, and it is probable that there is a non-sequence between the Lower Llandovery and the Tarannon. As the junction between the two can nowhere be clearly seen, the line adopted for the purpose of the map is that which separates pale grey shales and mudstones above from bluer mudstones with various forms of pentamerids—especially *P. undatus*—below.

However, at one locality (Pont Radin in Nant Alan) near the 1-mile stone from Llanfyllin, graptolites have been found which proved to belong to the *Monograptus turriculatus* zone, while at other localities brachiopods have been found.

The Wenlock-Ludlow rocks are mainly of the usual Welsh type of banded mudstone. Graptolites have been found at various horizons, but are abundant in the lower beds alone. These indicate the *Cyrtograptus murchisoni* zone.

The Denbighshire Grits are strongly developed to the west of the one-inch sheet, where three bands can be distinguished. The lowest appears immediately to succeed the *C. murchisoni* zone, while one of the higher grits forms Craig-fâch. On tracing the grits eastwards they rapidly die out, the lowest one alone extending in an attenuated form to Henrhyd-fawr. No sign of the grits is to be seen along the rest of this outcrop, but at the same horizon the beds are usually sandy and sometimes pass into fine-grained banded sandstones.

On the hill above Ty'n-y-celyn (east of Efail-y-cwm in Nant Alan), at about the horizon of the lower grit, a mass of calcareous conglomerate is found in the normal type of Wenlock sediment. The conglomerate consists of irregular lumps of fine muddy limestone, up to several inches in diameter, in a calcareous muddy cement, in which are also found rounded pebbles of hard black mudstone, which weather out on the surface. The conglomerate contains inter-bedded bands of calcareous mudstone, which show contorted bedding. In places graptolites and small brachiopods have been found in the matrix with the dark pebbles.

A similar, though much thinner, bed is seen at Adwy-wynt, to the south-west. Its exact horizon has not been determined, but the pebbles of dark mudstone fill up hollows scoured out of the banded mudstone to a depth of about 3 in. These peculiar beds must have been formed in shallow water that was subject at times to violent current action, which broke up the more or less solidified calcareous mudstone and eroded hollows in the beds that had already been deposited. The pebbles of black mudstone show such perfect rounding and are so unlike any rock

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exposed in the district, that it must be assumed that they were brought from a distance by strong currents near some older land-surface that was then undergoing erosion.

The mudstones below the conglomerate contain here and there a few similar looking dark pebbles scattered with no apparent method through the beds. These pebbles are much more phosphatic than those of the conglomerate and are probably of concretionary origin.

The main mass of the Wenlock-Ludlow series shows no features of particular interest, and the junction between the two stages cannot be traced without laborious fossil-collecting.

The rocks of the Llanfyllin area are thrown into a series of folds with axes ranging approximately east-north-east and west-south-west. This structure is best displayed by the junction of the Caradocian and Ashgillian stages, along which the Caradocian sandstones stand up as hills, while the soft mudstones of the higher stage tend to produce valleys. The anticlines are not symmetrical, however, for their northern limbs display gentle dips, while their southern limbs present vertical or even inverted dips. This indicates overfolding from the north. In similarly folded ground near Bwlch-y-cibau the Ashgillian and even the Lower Llandovery beds are involved.

South of Llansantffraid also, in the ground mapped by Mr. Smith, the Caradocian rocks are similarly folded. Some of the sandstones form sharp arête-like ridges, the two sides representing respectively the dip-slope and the steep scarp. The physiographical features are intimately related to the geological structure, both hills and valleys ranging themselves along synclinal and anticlinal axes. The hills, though of low elevation, possess a striking individuality rarely to be seen in the greater part of the area north of the Tanat valley. The Ashgillian rocks give rise to country of lower relief. The folding is mainly of post-cleavage date.

CARBONIFEROUS.

The 'Permian' rocks shown on the old map (61 N.E.) at Preston-on-the-Weald-Moors, between Wellington and Newport, have been found by Mr. Cantrill to be referable to the Keele Beds of the Upper Coal Measures. They consist of purple and lavender-coloured soft sandstone, yellowish-red sandrock, and salmon-coloured marl. Though their relationships to the surrounding formations are obscured by Glacial drift, it is probable that they are separated from the Bunter of Kinnersley on the north by a fault. Southward they appear to extend under the Drift towards Trench and Hadley, while south-westward they have been proved in a recent boring at Wellington.

TRIAS.

In the area south-west of Llanymynech, evidence has been obtained by Mr. Smith of the former extension or overstep[1] of the Trias across the Carboniferous rocks on to the underlying Ordovician. The evidence takes the form of a purple stain in

[1] 'Summary of Progress for 1915' (1916), p. 8.

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the Ordovician rocks of the hill-margin overlooking the plain of the Vyrnwy and Severn. This stained area, which forms a belt about half a mile wide, extends from New Bridge Vrynwy (about 1 mile S.W. of Llanymynech) for nearly two miles southward. A little hæmatite also occurs here and there in the joints and divisional-planes, and has encouraged prospecting for ore. In this tract the boulder-clay also is occasionally red in tint. Extensions of the stained belt farther southward may be expected.

Near Wem, in the ground mapped by Mr. Pocock, the Keuper Marl forms a feature, possibly due to faulting, trending north-eastwards from Shooter's Hill through Palms Hill and Brockhurst. To the south-east of this line the marl is practically free from drift and there are many small exposures showing red and grey shaly marls alternating with thin sandstones, the general dip being north-westward at about 2°.

At the Drumble the grey marls contain obscure plant-remains, and show traces of copper, while in many exposures the thin sandstones are ripple-marked and contain occasional salt-pseudomorphs.

To the north-west of this area the Keuper Marl is everywhere obscured by drift.

Farther south, in the district examined by Mr. Cantrill, between Shrewsbury, Wellington and Newport, the Bunter rocks, though almost wholly concealed by Glacial deposits, are exposed in the valleys of the Roden and Tern, and also at several points around Kinnersley. The greater part of the area is occupied by the fine-grained soft bright-red and brown sandstones that form the upper part of the Lower Mottled Sandstone, though outliers of the basement-beds of the Pebble Beds form low elevations at Sugdon, Longdon-upon-Tern, Crudgington, and Kinnersley. These outliers have yielded some dull-red and brown sandstones which, though containing small scattered pebbles of quartz, quartzite and igneous rocks, have proved useful for construction work on the local canals, railways and churches.

GLACIAL DEPOSITS.

The Glacial deposits of the Llanfyllin district examined by Mr. King, consist in the main of grey boulder-clay of local origin. Rocks foreign to the district are extremely rare, although on and north of the watershed between the Tanat and the streams draining into the Cain numerous boulders of the felsites of the Llangynog district can be seen. Striæ on rock-surfaces have been found at various points, and in all cases are directed down the valleys, showing that the lower layers of the ice, or perhaps merely the local ice, moved down the existing hollows. This does not preclude the existence of a main ice-sheet that moved transversely over the local ice from the main Welsh icefield towards the Shropshire plain.

Local patches of sand and gravel are found in the valleys, especially where a tributary enters a main valley. These gravels are probably referable to the latest phase of the glaciation, when small glaciers still occupied the valley-bottoms, the gravel being

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washed into the depression between the two ice-streams, and thrown down at the end of the spur dividing them. Pen-y-bryn Terrace at Llanfyllin is built on one of these gravel-spits.

The ground between the Bryngwyn Hills and the alluvium of the River Cain is covered with drumlin-like mounds of boulder-clay, elongated in the direction of the main valley. Near Llanfechain these drumlins apparently block up the old valley of the Brogan Brook which now, after flowing across a wide alluvial plain, cuts across the drumlins at right-angles in a small shallow gorge to join the Cain below Llanfechain. It is probable that the wide alluvial flat marks the site of what was once a small lake.

The Glacial deposits in Mr. Smith's district south of Llansantffraid are similarly of local or western origin. The chief large boulders are of Ordovician sandstone and limestone, and Wenlock grit. The largest specimen found, measuring 6 ft. by 3 ft. by 2 ft. 6 in., consists of fossiliferous sandstone. In an area of about 1½ square miles south and east of the Vyrnwy, and due south of Llansantffraid, the boulder-clay forms a series of twelve or more shapely drumlins rising from 80 to 100 ft. in height. Their longer axes are arranged either west-and-east, or slightly north-of-east and south-of-west.

Some patches of sand and gravel rise as rounded mounds through the Late-Glacial gravels near the main road about a mile south-east of Llansantffraid, and on the higher ground, 400 ft. above sea-level, a prominent tumulus — Hen Domen—has been erected upon a patch of gravel overlying the boulder-clay.

To the south-east of Ellesmere, Mr. Pocock reports that the drift-covered area of sand, gravel and boulder-clay displays a hummocky topography, with meres or peat-mosses in the hollows, as mentioned in the *Summary* for 1914, p. 15.

The sand and gravel forms a distinct belt trending south-eastward from Ellesmere through Cockshutt to Burlton, and is of considerable thickness, a well at Colemere Woods failing to bottom the sand and gravel at a depth of 75 ft.

The hummocky topography becomes less pronounced to the south of Cockshutt, where the belt of sand and gravel flattens out and reaches a lower level as it extends eastward towards Wem.

To the west of this belt of sand the high ground of Kenwick Park, Stanwardine and Petton is formed of boulder-clay, 120 ft. thick at Petton Farm, on which rest patches of coarse gravel and clayey sand, sometimes forming esker-like ridges with a south-easterly trend, as at Whinnett Hill.

The gravel at Kenwick Park, Stanwardine and Petton is coarse and for the most part unbedded. It contains striated blocks of Carboniferous limestone, fragments and pebbles of coal, and much slaty rubble of Welsh origin, including fossiliferous Lower Llandovery and Bala rocks, together with granite boulders and pebbles probably derived from the Lake District. Fragments of shells of marine species now living were noted in the gravel at Stanwardine, and also in the stiff boulder-clay near Weston Common, while at Petton, in the lower part of the pit near the church, fairly complete specimens have been found. A 3-foot

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boulder near Cockshutt has been provisionally identified as from the outer basic portion of the Carrock Fell gabbro.

Boulder-clay occupies most of the ground between English Frankton and Edstaston, north of Wem, with the exception of a belt of gravel following the course of the River Roden. The town of Wem is situated on a considerable spread of this sand and gravel.

Boulder-clay again occupies the ground between this belt and the outcrop of the Keuper at Shooter's Hill, Palms Hill and Brockhurst.

North-west of Wellington and thence towards Newport, Mr. Cantrill finds that boulder-clay overspreads much of the low country lying east of the River Tern, and extends under the Weald Moors around Kinnersley, past Preston, towards Trench. Much of it is red and loamy, and contains fragments of skerry sandstone from the Keuper Marl outcrop to the north, though the numerous pebbles (some of them striated) of Lower Palæozoic rocks, and of Lake District granites, show that some of the constituents are far-travelled. What are apparently the lower parts of this deposit consist of chocolate-coloured stoneless laminated silt, which seems to have been deposited in quiet water, possibly in a Glacial lake. This silt is dug for bricks at two pits near Longdon-upon-Tern.

Succeeding the boulder-clay an irregular sheet of sandy gravel, sand, and loam extends north-eastward through Admaston to Eyton on the Weald Moors, and thence south-eastward towards Trench. The sand is mainly of Triassic derivation and contains pebbles of Bunter and Keuper sandstone, as well as Welsh sandstones, Lake District rocks and occasional flints and shell-fragments. At Burcot, Orleton, Bratton, and Leegomery, the presence of angular pieces derived from the rocks of the Wrekin shows that some of the constituents were carried out on to the lower ground by ice or by water flowing northward.

Above this sheet of gravel and sand a second bed of boulder-clay sets in and forms the picturesque mounds ground of Dothill and Apley Parks near Wellington. Boulders, ranging up to 4 ft. in diameter, of granite and felsite are common throughout the district.

LATE GLACIAL, POST-GLACIAL, AND RECENT.

The Late-Glacial Flood-gravels of the Vyrnwy, described in previous Summaries of Progress[1], were found by Mr. Smith to form broad spreads upon both banks of the river south of Llansantffraid, breaking away in bluffs rising in places 30 or 40 ft. above the stream. To the south-east of a constriction in the valley of the Cain the gravels become mounds and contain numerous kettle-holes occasionally floored by peat, the largest being nearly 30 ft. in depth.

[1] For 1914, p. 17; for 1915, pp. 11–12.

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Small tongues of a Late-Glacial Clay known to underlie the gravel-fan that spreads out on the Shropshire Plain penetrate westward into the hill-country. An irregular tract of this clay, similarly related to the gravels, was mapped also in the drumlin-country south of Llansantffraid, on the east bank of the Vyrnwy. Another flat spread of what must be Late-Glacial as distinct from recent alluvium, occurs west of Deythur. These deposits are of fairly homogeneous, unstratified, and usually yellow, clay with few stones, and appear to owe their origin to mud, derived from the boulder-clay, that slid down the slopes to the lower ground almost immediately after the disappearance of the ice.

Low terraces, covered by brown loam with few stones, have been cut in these Late-Glacial beds at a later period, when the volume of the streams had diminished. The recent alluvium is a brown loam with occasional seams of rather coarser material. In the wider parts of the flood-plain it overlies the gravels that appear to form the river-bed.

Along the valley of the Tern Mr. Cantrill finds that Late-Glacial gravels form terraces between Crudgington and Walcot. They consist of materials derived from the earlier drifts, with an increased proportion of flint-pebbles.

The Weald Moors, which occupy a large low-lying area around Kinnersley (between Wellington and Newport), are covered with a thick deposit of peat and peaty alluvium, in which tree-trunks and roots are occasionally discovered. Popular opinion regards the moors as the site of a lake, but no proof of this theory has been obtained. The sluggish drainage of the district probably gave rise to swamps and later to dense woodlands, which further impeded the waters and ultimately led to a thick growth of peat. That the peat was thicker and more extensive before the Marquis of Stafford's drainage scheme was carried out in 1820, is shown by the stilted condition of the trees still growing on and around the peat-covered ground.

(2) WARWICKSHIRE AND STAFFORDSHIRE DISTRICT.

W. Gibson, D.Sc., District Geologist.

E. E. L. Dixon, B.Sc., A.R.C.S.

R. L. Sherlock, D.Sc., A.R.C.S.

T. H. Whitehead, B.Sc., A.R.C.S.

The surveying of the South Staffordshire Coalfield (sheets 167 and 168) and of the region lying to the west (sheets 139 and 153) was continued.

SILURIAN.

The small inlier of Silurian rocks exposed in the crest of the Netherton Anticline at Saltwells, between Brierley Hill and Netherton, has been mapped by Mr. Whitehead. The succession determined by Messrs. King and Lewis[1] in 1912 corresponds

[1] *Geol. Mag.* for 1912, pp. 437–43, 484–91.

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closely with that established by Miss Elles and Miss Slater[1] at Ludlow, and consists of:—

4. Red Passage Beds, red and purple marls and sandstones.
3. Temeside shales, with bone-beds.
2. Downton Castle Sandstones.
1. Upper Ludlow Shales, with bone-bed at top.

For the purposes of the map, Nos. 3 and 4 have been grouped together. In their paper of 1912, Messrs. King and Lewis described the Red Beds (4) as Old Red Sandstone, largely on the grounds that the 'lingula' fauna was not found by them above the Temeside Shales. Lingula has since been found in the Red Beds, and in a later paper[2] Messrs. King and Lewis give reasons for regarding them as of Downtonian (Ledbury Passage Beds) age, rather than Old Red Sandstone.

The brine well at Saltwells seems to have been sunk into these red beds, but it appears that they here have a covering of Coal Measures, as beds containing traces of plant-remains, and having the appearance of Coal Measures, are exposed in the banks of the Blackbrook, immediately to the north. The outcrop of the red beds seems to be truncated by a fault some two hundred yards north of the Saltwell.

COAL MEASURES.

The mapping of the Upper Coal Measures and Middle (Productive) Coal Measures south of the Bentley Faults has been continued by Mr. Whitehead. The evidence from shaft-sections, and such observations as can be made at the surface, show that the passage from the grey Productive Measures to the red and purple Old Hill (Etruria) Marls is gradual. Red marls and 'gritty' rocks are occasionally recorded at several levels in the Productive Measures; and a grit of distinctly 'Espley' type occurs about 15 ft. above the Brooch Coal in Messrs. Doulton's smaller clay-hole at Saltwells.

Whenever the Upper Sulphur Coal is shown in a section, mention is almost invariably made of 'red ground' and 'mingled ground,' together with 'rock' and 'pebbly rock,' above it. It seems convenient therefore to regard this coal, which when present is always about 300 ft. above the floor of the Thick Coal, as marking the top of the 'Middle Coal Measures,' or grey productive measures. This arrangement, which was that adopted by J. B. Jukes[3], has the advantage of including in the Productive Series all the coal seams that have ever been worked. When the Upper Sulphur Coal is not present, it is usually the case that 'red ground,' red 'marl,' etc., begin to appear in the records of shaft sections at about 300 ft. above the Thick Coal. At Birchtree Coppice, near Quarry Bank, and at Mushroom Green, there is a marked development of grits and conglomerates, at a level which seems to correspond sufficiently nearly to that at which the

[1] *Quart. Journ. Geol. Soc.*, vol. lxii, 1906, p. 195.
[2] *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, pt. 2, 1917, p. 90.
[3] 'The South Staffordshire Coalfield,' *Mem. Geol. Surv.*, 2nd ed., 1859, pp. 28–31.

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Upper Sulphur Coal commonly occurs, to justify the use of these beds as a base for the Etruria Marls. Similar conglomeratic and gritty beds are strikingly developed about Dixon's Green and Tansley Hill, but here they seem to persist to a higher level. In the absence of such beds at or near the plane of division, it is only possible to indicate vaguely the boundary between the area of the Productive Measures outcrop and that of the Etruria Marls, by the aid of information as to depth of the Thick Coal derived from numerous shaft-sections.

The thickness of the Old Hill Marls is about 300 ft. near Old Hill, and probably less than this near Blackheath and Cakemore. Towards the north they increase to about 350-400 ft. east of Dudley Port Station.

The Halesowen Beds come into the area surveyed near Cakemore and Blackheath. In the Cakemore marl-pit there occur yellowish grits and conglomerates which rest on purple marls, and which have been identified by Mr. Kay[1] as belonging to his 'Witley Group' of the Halesowen Sandstone series. Having regard, however, to the level of the Thick Coal under the marl-pit, where it stands at 149 ft. above sea-level, giving a depth of less than 450 ft., it seems more reasonable to regard these arenaceous beds as 'Espley' rocks in the Etruria Marls. Very similar beds occur in the Etruria Marls near Tividale and Rounds Green. On the higher ground of the golf course, south of Cakemore marl-pit, and at Round Hill Farm, greenish sandstones and conglomerates of the Halesowen series appear, and are thrown by the eastern boundary-fault against the red beds of the Hamstead group about midway between Round Hill Farm and Brand Hall. Similar indications of Halesowen Sandstone appear on the higher portion of the ground enclosed by the munition factory north of Hurst Green, and also at Rowley Regis Station. The brick-pit, about 250 yards south-west of the station, exposes greenish-grey sandstones overlain by grey clays with signs of a thin coal and yielding many blocks of spirorbis limestone. These clays belong to Mr. Kay's Halesowen Coal and Clays group[2], and are thus well above the base of the Halesowen Beds as a whole. It appears probable, therefore, that the Halesowen Beds outcrop may extend sufficiently far north to include the site of the coal-shafts about 300 yards north of the brick-pit and near Rowley Regis Station, though the depth to the Thick Coal in these shafts is stated to be only 606 ft. South of Old Hill, and in most localities farther to the north, Etruria Marls appear at the surface where the Thick Coal is at a depth equal to, or even considerably greater than this. It is, however, not to be expected that a plane of division, based on purely lithological characters, should maintain a constant position with reference to a datum, such as the Thick Coal floor, when traced over even comparatively short distances. This is especially true of a plane intended to separate two such variable groups as the Etruria

[1] *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, p. 441.
[2] *Op. cit.*, p. 443.

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Marls and the Halesowen Beds, the passage from one to the other of which, is, moreover, so gradual.

Hamstead Beds.—On the upcast side of the Eastern Boundary Fault, south of Oldbury, brown-red, soft sandstones appear, with lenticles of coarse limestone-conglomerate, the latter giving rise to conspicuous features south of Langley Green and near Brand Hall. Pebbles of chert and of limestone, chiefly Carboniferous, but including some Silurian,[1] are abundant in these conglomerates. The proportion of limestone-pebbles relative to those of other kinds, appear to increase as the exposures are followed from south to north, and may be as high as 50 per cent. In a gravel-pit near Bristnall Fields, east of the Bristnallhall-road, and also in the lane called George-road, leading to Warley Woods, there occur breccia-beds, with small subangular pebbles, interbedded with soft sandstones and marls. Pending further evidence from the ground to the south-west as to the persistence of these breccia-bands, no attempt has been made to draw precise boundaries for them.

Igneous Rocks.—The dolerite and basalt of the Rowley Hills may be seen intruded into Etruria Marls near St. Giles's Church, Rowley Regis. There it is in the form of small dykes or sills in the marls, some of the sill-like intrusions being only an inch or two in thickness. No perceptible alteration is produced in the marls.

South of Netherton Church, the small exposure of basalt in the canal-section seems to afford evidence that the intrusion was later than the formation of the fault there exposed to view. The basalt has the appearance of running up the scarp face of massive Downton Castle Sandstone, where that rock is truncated by the fault, and does not cross the fault-plane. About 30 yards to the south, however, where the sandstones against the fault are flaggy, the igneous rock crosses the fault and intrudes itself as sills between the flags. Where the basalt is intruded into the red Downtonian sediments in the canal-bank, some metamorphosis of the sediments has taken place.

Faults.—Mining-plans make it clear that the Russell's Hall Fault, along the western flank of the Rowley Hills, is a complex system of fractures occupying a strip of ground from one to two hundred yards broad. It is in fact part of a belt of much faulted ground nearly half a mile broad. South of Dixon's Green the Russell's Hall Fault is stated to have no hade in the Thick Coal, and to vary in the amount and direction of its hade as it is followed upwards. The downthrow here is believed to be 150 ft. to the south-west, and this throw increases towards the south, but the amount, so far as can be ascertained, has not been actually proved, as the fault usually forms the boundary of properties, and is in consequence never crossed by any workings.

The Eastern Boundary Fault is well marked between Cakemore and Warley by the contrast between the grey Halesowen

[1] W. W. King, *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 115.

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Beds on the downthrow side and the red Hamstead Beds on the upthrow side. The throw here must be about 1,100 to 1,200 ft. Smaller faults to the west throw the Halesowen Sandstone down to the east. There is, in fact, a belt of faulted ground extending over a considerable distance east of Cakemore and Oldbury. The trial-boring made some years ago between Langley Green and Londonderry was evidently situated in this disturbed belt, as was shown by the faulted condition of many of the beds passed through.

In the district, surveyed by Mr. Dixon, around Bushbury and Hilton Park, on the western margin of the South Staffordshire Coalfield, north of the Bentley faults, the structure is similar to that at Shareshill and Saredon, as described in the Summary of Progress for 1915, pp. 12–13. Barren red Upper Coal Measures, referable to the Keele and Hamstead Beds, occupy much of the surface, and the Bunter Pebble Beds are confined to isolated outliers on the highest ground. As elsewhere in the Midlands, the Hamstead Beds include water-bearing sandstones and breccias or conglomerates, in which subangular yellow and red cherts derived from the Carboniferous Limestone are abundant. Pebbles of Limestone, though more local, also occur. Similar rocks occur around Lilleshall, and are doubtless referable to the Hamstead Group.

TRIAS.

The examination of the Triassic Rocks which separate the South Staffordshire Coalfield from that of Coalbrookdale, has been continued. Great variability in the development of the three sub-divisions of the Bunter is met with. In the Bushbury area, for instance, Mr. Dixon finds that the Bunter commences with the Pebble Beds, the Lower Mottled Sandstone being overlapped or not developed. Farther north, beyond Penkridge, the Upper Mottled Sandstone is also wanting; but in the Newport district to the west, and generally along the margins of the Coalbrookdale Coalfield, all three sub-divisions are represented.

In the Bushbury district the Bunter occurs in the form of outliers resting on high ground composed of Upper Coal Measures. Farther west Bunter Sandstone, succeeded by Keuper Sandstone and Keuper Marls, forms a broad tract running parellel with the Upper Coal Measures. The junction of this main outcrop with the Upper Coal Measures is not seen, but as generally thought, it is probably a fault, though not necessarily one of large magnitude.

In the Newport district, the Lower Mottled Sandstone presents in several places, and through a thickness of several feet, a remarkable development of 'millet seed' sand, the grains being large, uniform in size and nearly spherical.

East of Brewood two deep borings for water are in progress, and the cores have been examined by Dr. Sherlock. The one at Somerford, after passing through Keuper Marl and Keuper

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Sandstone, has proved 200 ft. of non-pebbly Bunter Sandstone. The other, at Slade Heath, shows that the Drift rests on Bunter Sandstone containing a few pebbles.

South of Smethwick, in the area surveyed by Mr. Whitehead, around Warley Abbey, the Bunter consists of lenticles of sandrock and of semi-consolidated pebble-beds. What appears to be an outlier of these beds survives on the high ground at Hilltop, near Bristnall Fields. The Lower Keuper Sandstone in the Newport area is a typical, coarse, conglomeratic, brown rock, easily distinguishable from the Upper Mottled Sandstone. Southwards, towards Boscobel, Dr. Sherlock finds the Keuper Marls passing down into soft, brick-red sandstones, resembling Lower Mottled Sandstone, and farther east, near Corven and Featherstone, Bunter and Keuper Sandstones are difficult to distinguish.

GLACIAL.

In the district round Newport (Salop) mapped by Mr. Dixon, the glacial deposits fall into three groups:—(1) unbedded clayey-drifts; (2) high-level gravels and sands; (3) low-level gravels, sands and laminated loams and clays.

The unbedded drifts, which are of the nature of 'till,' bear no particular relation to the topography. The high-level drifts cover some of the highest parts of the Keuper Marl outcrop east of the Bunter ridge, fringing the Coalbrookdale Coalfield. The third set appears to have been laid down partly in a lake covering the site of Newport, and the ground to the west, and partly by waters escaping from this lake into valleys draining to the east and south as surmised by F. W. Harmer.[1]

A stiff chocolate-clay, with a local development of loose red sands at its base, occupies the low ground in the Shifnal area. Dr. Gibson notes that this clay is of sufficient thickness to prevent much of the rainfall from percolating into the underlying Lower Mottled Sandstone, and that a geological map, on which superficial deposits are omitted, gives no clue to the character of the soil and subsoil. In the Keuper Marl area, round Boscobel, surveyed by Dr. Sherlock, glacial sands and gravels attain a considerable development, and give rise to a light soil of less agricultural value than that formed out of Keuper Marl.

The well-marked features determined by the 'solid' geology of the Cakemore and Warley area are observed by Mr. Whitehead to die away northwards under a blanket of unbedded pebbly drift. Similar material, but with a larger admixture of clay, lies on the watershed at Blackheath, at a height of about 840 ft. West of Rowley Regis, drift is absent, except for a few signs of it, in the form of clay with pebbles, near Mousesweet, near Old Hill, and scattered Bunter pebbles at Quarry Bank. A small patch of pebbly drift lies at a height of 800 ft., north of Turner's Hill, on the Rowley ridge itself.

[1] *Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, p. 478.

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(3) LEAD, ZINC AND COPPER MINES.

The Northumbrian area was examined by Dr. Stanley Smith, the rest of the Pennine Chain by Mr. Carruthers. Throughout this region, the great majority of the productive veins are in Carboniferous Limestone and Yoredale strata, though a few traverse the Millstone Grit also. They are characterised by a comparatively rapid impoverishment in depth, generally because the fissures "pinch out," but occasionally on account of replacement by other minerals. It is rare to find a vein carrying commercial quantities of ore below 100 fms., and it is not surprising to find that after centuries of working, most of the mineral fields, taken as a whole, show signs of exhaustion. There are notable exceptions, however. The famous "flats" of the Boltsburn Mine, in Weardale, discovered 27 years ago, are still in full work. They appear to be metasomatic replacements of the limestone, parallel to, but rarely in contact with, a thin vein, which has presumably acted as a "feeder."

The Alston Moor country continues to be an important producer, especially for zinc-blende, of which considerable reserves exist. Metasomatic 'flats' are found here also.

Most of the Derbyshire mines, once so numerous and so active, closed down many years ago. Millclose Mine, marked by immensely rich chamber-deposits on either side of the lode, is still in active work. The headings are now far under the Yoredale Shales, nearly two miles from the limestone-outcrop. Most of the innumerable veins scattered over the limestone massif in this country are probably exhausted, but if some efficient means could be devised to cope with the heavy underground water, some of the great "rakes," now drowned out, might again produce galena in quantity.

Interesting evidence as to the date of the Derbyshire ore-deposits is provided by the small lead- and copper-working at the Snelston Mine, near Ashbourne. The ores are found in a fault bringing down Keuper Marl against Carboniferous Limestone, so that, here at any rate, the mineralisation seems to be definitely post-Triassic.

The occurrences of galena and blende in the Carboniferous Limestone and Chert series of Flintshire and Denbighshire were examined by Mr. Bernard Smith, with a view to bringing up to date the detailed account given in the Memoirs on the Geology of Flint, Mold and Ruthin (1890) and the Geology of the Coasts adjoining Rhyl, Abergele and Colwyn (1885).

The abandoned mines near Minera, in ground recently surveyed, were also studied.

The chief mines still in work are in the Halkyn District, but others are ready to reopen in both this and the Holywell districts if deep drainage can be secured or labour-conditions permit. In depth the lodes appear to carry a higher proportion of blende than galena. The future development of this region depends upon a successful unwatering of the ground. The old

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Halkyn Tunnel, driven southward as far as the Llyn-y-pandy Lode, about four miles south of Halkyn, at approximately 200 ft. above sea-level, no longer serves the purpose, for most of the mines unwatered have been worked down to, or below, its level. Further work in these mines entails costly pumping.

It is now proposed to carry the Milwr or sea-level tunnel, which has already proved several of the lodes in depth in the Holywell area, southward into the Halkyn district, and extend it eventually into the Llanarmon field. It is hoped that in that area numerous veins, that have yielded richly in the past, may be found to be prolific in the eastern parts of their courses. The southern extremity of this tunnel is now at the northern boundary of the Halkyn Mines District Drainage Area, and about 200 ft. below the old tunnel.

During the closing stages of the war a pumping-scheme, financed by the Government, was commenced at North Hendre Mine, to unwater several bearing lodes below the Halkyn Tunnel level, but this scheme is in abeyance.

Little is being done at the present time in the Minera district, chiefly owing to the fact that the great Minera veins contain blende, but little galena, in depth, and pumping-charges are prohibitive.

In the Minsterley district of Shropshire, again, the future of the mines depends upon deep drainage. Here the ores of lead and zinc occur chiefly in the Mytton Beds overlying the Stiper Stones quartzite and beneath the Hope Shales—all of Arenig age.

The Leigh Adit Level (399 ft. O.D.) has been completed as far as the Milne Shaft in the Hope Valley, and is now being driven southward to cut a large series of veins formerly worked in the old "Gravels" and "Grit" Mines. Should these prove to be rich beneath the old workings a promising future is assured for the Shropshire Mines. For the Bog Mine pumping has been proposed. At the present date the chief product of the district is barytes, got from shallow levels above water-line.

Mr. Smith also examined occurrences of lead- and zinc-ores in the Ordovician and Silurian rocks, near St. Asaph, in Flintshire, Llansannan, in Denbighshire, and Llanrhaiadr and Llangynog in Montgomeryshire. The Pennant Mine, St. Asaph, is alone in operation.

Some scattered occurrences of copper-ore were also investigated in Denbighshire and Shropshire.

The mines for lead, zinc and copper in Cornwall, Devon, Somerset, Shropshire, Cheshire, Carnarvonshire, Merioneth and Anglesey, were visited by Mr. Dewey.

In Cornwall and Devon, the lead- and zinc-ores occur principally in lodes which course north and south and frequently underlie east. They traverse slates and sandstones of pre-Devonian, Devonian and Carboniferous age. Their gangue

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minerals consist of calcite, fluorspar, barytes, quartz and chalybite. Galena and blende often form an intimate complex; but, blende is the principal constituent in some lodes, as at Wheal Sally and Wheal Alfred. In North Cornwall, where the lodes appear in and near flows of lava, galena is the dominant mineral; it is rich in silver and is frequently accompanied by the ores of antimony.

Lodes bearing galena and blende were formerly worked by opencast pits sunk in the Carboniferous Limestone of the Mendips, and calamine and blende were also mined in the Triassic Basal Conglomerate on the flanks of those hills. No mines, however, are now in work and the dumps have been thoroughly worked over.

Ores of copper, lead and cobalt occur, mainly as carbonates, in the Keuper Sandstone and conglomerates of Alderley Edge, Cheshire. In the underground workings the distribution of the ores is seen to be patchy. Percolating waters have impregnated the sandstone with ores in the neighbourhood of faults and the drainage-waters in the mine are coloured a brilliant green by carbonate of copper. Rich impregnations of galena up to 3 ft. in length can be seen in several of the levels. The mineral envelops the grains of sand and even the pebbles of the conglomeratic beds. The normal 'ore' consists of fine-grained sandstone with a cement of green and blue carbonates of copper.

At Grinshill and some other workings near Shrewsbury, copper-ores have been mined in the New Red rocks and appear to be identical in mode of occurrence and of formation to those of Alderley Edge.

Near Llanrwst, in Eastern Carnarvonshire, there is a large group of mines working lead- and zinc-ores, in most cases by day-levels above adit. The country rock is of Lower Palæozoic age and is fissured by two sets of lodes which course either north and south or east and west. These lodes, in many cases, are mineralised 'shatter-belts' and consist of brecciated country-rock cemented together with calcite, galena and blende. There are indications of a succession of minerals in the lodes from east to west. The Aberllyn Lode consists mainly of brown blende in the form of shear lenticles, galena being rare. A little farther to the west galena forms the principal constituent with a calcite gangue, as at Parc Mines; quartz as a gangue then appears at Old Llanrwst Mine, where it forms a remarkable spongy mass of bipyramidal crystals embedding idiomorphic crystals of galena. Almost due north from these mines pyrites becomes an important accessory. At Cae Coch it is the principal ore and has been wrought.

In Anglesey metallic copper is still being obtained regularly from the drainage-waters of the Parys Mountain Mines by precipitation on scrap-iron; but further mining is not at present anticipated. Some auriferous copper-ore is being mined at Rhos-mynach, Anglesey, and from the old gold-mines of Figre

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and Clogau, near Dolgelley. Zinc- and lead-ores are mined at Moelwyn and Bwlch-y-plwm Mines.

In the Lake District (examined by Mr. Eastwood), ores of lead, zinc and copper are found in Lower Palæozoic strata. The veins around Keswick are in the Skiddaw Slates; those of the Greenside and Coniston fields are in the Borrowdale Ashes, while in the Caldbeck Fells, both rock-groups occur, associated with a complex of igneous rocks.

Most of the veins are filled with broken 'country-rock,' cemented with mineral matter. The leading constituents of the gangue are quartz and barytes, the latter, when in bulk, being restricted to the higher parts of certain veins. Some of the so-called 'lead' lodes contain more blende than galena. Although there are numerous exceptions, 'copper' veins usually trend east and west, hading south, while 'lead' and 'zinc' veins range within 45° either way of north and south, and dip to the east. 'Copper' lodes are sometimes shifted by those carrying 'lead,' while the latter are frequently displaced by barren east and west cross-courses.

The chief ores now raised are those of lead and zinc. Over the whole area, as compared with the Pennines, the galena is notably rich in silver. The amount varies greatly, and seems to have some relation to the presence of barytes. In veins where barytes is abundant, as at Force Crag, the silver content is high —over 30 ozs.—while in lodes carrying little or no barytes (Thornthwaite Threlkeld) it is low—about 10 ozs. of silver per ton of pig lead.

The only zinc-ore of commercial importance is blende. When this occurs with barytes the difficulty of separation, almost insuperable in the old days, has now been got over by oil flotation. The Elmore plant at Force Crag gives a clean blende concentrate, while the crushed barytes is re-dressed and sold as 'barytes sand.'

The lead-zinc ore mines now active are Greenside, Thornthwaite, Threlkeld and Force Crag. Brundholme in Glenderaterra Valley has been re-opened, while at Goldscope in Newlands Vale an attempt is being made to locate the intersections of the copper-lode and 'Sealby's lead vein' in the hope of proving an ore-body similar to that of the great lead-bunch of the Goldscope lead-vein.

No copper-ores are being raised at present, though Coniston, Goldscope and Caldbeck Fells were large producers many years ago. The extensive dumps at Coniston, averaging 1½ ozs. of metallic copper per ton, have recently produced a few tons of sheet-copper by an electrolytic process, but work is now suspended during reconstruction. The chief ore is chalcopyrite, which is associated with iron and arsenical pyrites. Secondary malachite and chrysocolla also occur, but not abundantly.

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(4) Borings for oil in Derbyshire and Staffordshire.

From June to October Mr. Bromehead was stationed at Chesterfield and kept the seven Derbyshire borings under continuous observation, examining all samples of the rocks pierced as they were obtained. In Staffordshire, similar work was done by Mr. Eastwood, who was surveying in that district. By October progress in Derbyshire had become so slow, owing to engineering difficulties, that thenceforward occasional visits only were necessary to obtain all the geological information available.

An account of the progress made up to September, 1919, has been inserted in the second edition of the Special Report on the Resources of Mineral Oil, Kimmeridge Oil Shale, etc., now in the press. The depths and the formation reached by December 31st. are given in the following table:—

Well.	Depth. Sept., 1919.	Depth. Dec., 1919.	Formation reached.
	ft.	ft.	
Ridgeway...	2,815 ...	2,996 ...	Carboniferous Limestone.
Renishaw ...	3,650 ...	3,645 ...	Limestone Shales.
Brimington	2,650 ...	2,660 ...	Limestone Shales.
Heath ...	2,897 ...	2,955 ...	Limestone Shale or Millstone Grit.
Hardstoft ...	3,112 ...	3,112 ...	Carboniferous Limestone.
Ironville 2...	3,570 ...	3,570 ...	Carboniferous Limestone.
Ironville 1...	2,430 ...	2,580 ...	Carboniferous Limestone.
Werrington	1,282 (Oct.)	1,920 ...	Pendleside Series.
Apedale ...	1,350 „	1,350 ...	Lower Coal Measures.

The amount of oil obtained at Hardstoft to the end of the year was 1,900 barrels as compared with 849 barrels to October 1st. The large increase is due to a bailing-test having been made early in December. When the level of the oil was kept at a depth of 1,600 ft., the yield was 20 barrels a day, while with a level of 3,000 ft. as much as 35 barrels was obtained.

At Ridgeway a heavy flow of salt water was met with at 2,898 ft. This water apparently came from the Limestone; it had a temperature of about 110° F. and contained some hydrogen sulphide.

The seepages and other evidence for the presence of petroleum in the Lower Carboniferous rocks of Derbyshire, on which, in part, this exploration was based, lead Mr. Bromehead to suggest that it is the lower part of the Limestone Shales, rather than the Limestone that contains the oil. In many parts of the world, California, Mexico and Galicia for example, where petroleum is indigenous to shales, it is found that commercial supplies are only obtained when a suitable reservoir-rock is brought into oblique contact with the shales. When a porous rock cuts across the bedding of the shale, owing either to unconformity or to faulting, the oil passes by capillarity along the laminæ of the shale, which is impervious in a direction at right angles to the bedding, and accumulates in the porous rock. It

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would appear that the conditions in Derbyshire are of this nature. The section at Kelham indicates that the Millstone Grit is faulted against the Limestone Shales.

At Hardstoft an important fault, proved in adjacent collieries, may be estimated to intersect the boring at a depth of rather more than 3,000 ft. This fault may possibly be connected with the disturbance indicated at Kelham. Its effect at Hardstoft would be to bring limestone into oblique contact with shales, and as a fact between the depths of 3,070 ft., where oil was struck, and 3,112 ft. the samples consist of a mixture of shale and limestone. Again, the character of the oil obtained, its light gravity and colour and low sulphur-content, indicate a shale rather than a limestone as the parent rock.

This theory of the origin of the oil and of the conditions requisite for its accumulation account for the success at Kelham and Hardstoft, provides a reason for the failure at Ridgeway and the two Ironville borings, where the structure was regarded on the anticlinal theory as exceptionally favourable, and does not afford much expectation of success at the remaining wells.

(B)—SCOTLAND.

The surveying of the districts which were in hand in 1914 was in part resumed in 1919. The work had been proceeding in two districts in the Highlands, viz.—

(1) West Highland District under the late Dr. C. T. Clough.

(2) North and Central Highland District under Mr. L. W. Hinxman (now retired).

at the same time revision of the coalfields was proceeding in:—

(3) Ayrshire (Kilmarnock District) under Dr. Clough.

(4) Renfrewshire and South Lanarkshire District, under Mr. Hinxman.

No field-work was done in the West Highland District during the year.

(1) North and Central Highland District.

The igneous rocks of Lower Banffshire and North-west Aberdeenshire (Sheets 86 and 96) have been divided by Mr. Read into an Older or largely pre-foliation series and a Younger or post-foliation series.[1] The Younger Series occurs in two great masses—the Huntly Mass, which was described in last year's Summary of Progress[2]; and the Insch Mass.

[1] 'Summary of Progress' for 1918, *Mem. Geol. Survey*, 1919, p. 24, *Geol. Mag.*, 1919, p. 364.

[2] *Loc. cit.*, p. 28.

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The Insch Mass.

The northern part, which alone comes within Sheet 86, extends eastwards from the Old Red Sandstone of the Bogie Valley for 16 miles almost to Old Meldrum; and northwards for about 2 miles into Sheet 86. The direction of elongation of this and of the Huntly Mass, coincides mostly with the strike of the neighbouring metamorphic rocks.

The rock-types found in the northern part of the Insch Mass are olivine-norite, hypersthene-gabbro, quartz-diorite, syenite and granite. Other types—troctolite, probably peridotite, etc.—occur outside Sheet 86; and until these occurrences have been examined, consideration of the relative ages of the different rock-types must be held over. The order given above is likely to be that of relative age, beginning with the oldest.

Olivine-norite.—The main part of the northern portion of the Insch Mass is formed by two rocks, an olivine-norite and a hypersthene-gabbro. These are easily separable in the field and under the microscope, but whether they are two independent intrusions or only phases of one intrusion, is not yet determined. The olivine-norite forms the north-western part of the gabbro of the Insch Mass. In hand-specimen it is a coarse, dark-greyish rock. It weathers to a great depth in spheroidal masses which contain oval nuclei of fresh rock, the final result being a coarse reddish sand and a soil of great fertility. In slice, the rock is seen to consist of labradorite, olivine, hypersthene, augite, biotite, hornblende, magnetite and apatite. The felspar occurs in large fresh crystals. The olivine is abundant in large rounded grains often bordered by pyroxene. The hypersthene forms large prisms or fingered plates with well-marked pleochroism in green to pink tints, and commonly occurs as a border to rounded olivine-masses. The monoclinic pyroxene forms stout prisms, greenish in colour, with well-marked basal striation and is usually much subordinate to the orthorhombic variety. Yellow to deep-brown biotite builds large plates, often associated with iron-oxide masses. Brownish-green hornblende is of secondary origin and borders the pyroxenes. Apatite is abundant in small clear hexagonal prisms. Variations from this main type are formed by differences in the relative amounts of the two varieties of pyroxene. Occasionally the rock approximates to an olivine-labradorite rock, but then it is easily distinguishable from the troctolites of the Huntly Mass.

Hypersthene-gabbro.—This type of gabbro is found in general in the north-eastern part of the Insch Mass. It is finer in grain than the olivine-norite and weathers into rectangular slabs. In slice it is characterised by an equigrained structure and is made up of labradorite in stout crystals, vividly pleochroic hypersthene-prisms, marginally altered to fibrous green hornblende, abundant augite-prisms with a diallage-structure, and rather large irregular clots of magnetite. Variations from the main type are brought about by changes in the relative amounts of the two pyroxenes.

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Quartz-diorite.—This rock covers much ground in the parish of Kennethmont. It is a fine-grained greenish-grey rock composed of plagioclase, quartz, hornblende, biotite and accessories. The felspar varies from oligoclase to andesine and builds well-formed crystals, often zoned. Quartz is interstitial to the felspars and somewhat variable in amount. Hornblende, yellow-green in colour, is associated with the yellow to black biotite in clusters and rude groupings. Kernels of pyroxene have been observed in the hornblende. The accessories are magnetite, sphene and apatite.

Syenite.—A rock meriting the name syenite is found in the Wardhouse district. It is a coarse rock, showing in hand-specimens large pinkish felspars and small patches of hornblende and biotite. It is usually much weathered, yielding a coarse felspathic sandy soil. In slice, the felspars are seen to be microcline and oligoclase; the former occurs in large plates of last crystallisation, the latter forms turbid well shaped crystals. Quartz is rare. The ferro-magnesian constituents consist of biotite in large, ragged, yellow to deep-brown plates, and of a deep-coloured brownish-green hornblende. Magnetite and zircon occur as accessories. Near Wraes, the syenite has altered the olivine-norite into a rock with large plates of black biotite.

Granite.—Intimately associated with the syenite, and probably not separated in time, is a fine-grained pink granite, well seen near Weets in the Wardhouse district. In slice, this rock is composed of plentiful quartz, abundant microcline and a finely striped oligoclase in large plates. Ferro-magnesian minerals are rare and limited to small patches of a dark greenish-brown hornblende. A similar rock occurs in small knobs breaking through the gabbros at Knockenbaird and Jackston.

Dyke Rocks of the Insch Mass.

Lamprophyre.—In the syenite-area about the Shevock Burn thin dykes of a very rotten lamprophyre are found. The pink- and green-speckled rock shows small round pea-like patches of a dirty-white felspar.

Quartz-dolerite.—A forty-foot quartz-dolerite dyke occurs in the olivine-norite at Auchinbradie, north of Insch. It presents well-marked chilled edges against the norite. In slice, it is seen to be composed of quartz, labradorite, augite and iron-oxide in coarse ophitic association. The quartz-dolerite has an east-and-west trend, and on its line, about a mile west of Auchinbradie, there is a small outcrop of a beautifully variolitic basalt. Other quartz-dolerites with a similar trend occur in the slate and knotted schist areas to the north of the Insch Mass at Blackford, Rothienorman, Petty and Minnonie (Fyvie).

Granite.—In the Shevock Burn several small dykes of acid rock are found, characterised by inclusions of numerous small pieces of hornfelsed slate. The acid dykes contain pink garnet and, according to Dr. Mackie of Elgin, orthite.

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Cordierite-Norites of the Insch Mass.

It was shown in last year's 'Summary of Progress'[1] that cordierite-norites, formed by incorporation of sediment in the norite of the Huntly Mass, are widespread. In the Insch Mass, cordierite-norites and associated rocks capable of a similar explanation have been discovered in the Saphook district, west of Old Meldrum. Here the norite of the Insch Mass gives place to a rock which, while preserving proof of its igneous origin, is crowded with ghosts of sedimentary xenoliths in an advanced state of incorporation in the norite-magma. The minerals of this set of contaminated norites are quartz, various plagioclases, cordierite, biotite, garnet, spinel, sillimanite, hypersthene, zircon and magnetite. This mineral assemblage is similar to that already known from the cordierite-norites of the Huntly Mass. The Saphook group of contaminated norites occurs on the margin of the Insch Mass; the contiguous sediments are the gneiss and mica-schists of the Old Meldrum area.

Contact effects of the Insch Mass.

The contact alteration produced by the igneous rocks of the Insch Mass on the slates on its northern border was briefly mentioned in last year's 'Summary.'[2]

The gradual passage from unaltered well-cleaved slate to a massive spotted rock and finally to a true hornfels was there described. Further work has confirmed those observations. The spots of the spotted-rock zone are due to the heaping together of dusty materials in areas of incipient crystallisation of cordierite and andalusite. Nearer the igneous rocks, the spots give place to definite crystals of andalusite and patches of cordierite, accompanied by sillimanite, garnet and the reddish biotite of the cordierite-hornfelses. At the junction with the igneous rocks, granular pyroxene-hornfelses are found, characterised by the occurrence of pyroxene in small rounded granules. Small plates of biotite, scarce brown hornblende-prisms, grains of clear plagioclase and quartz complete the rock. Some of the cordierite-hornfelses are banded with vividly pleochroic grains of hypersthene. Such spotted rocks and hornfelses are demonstrated to be the result of contact action of the Younger Igneous rocks on slate, but at the eastern end of the Insch Mass a series of andalusite and cordierite-bearing rocks of a different type is observed. These andalusite-schists are especially well seen in the Ythan Valley about Fyvie, whence they run southwards into the aureole of the Insch Mass. They have no kind of relation to any of the masses of Younger Igneous rocks exposed at the surface, but, lithologically and structurally, are comparable to the Older Andalusite-Schists already described from other parts of Sheets 86 and 96.[3] Unfortunately, exposures of the Fyvie

[1] 'Summary of Progress for 1918,' *Mem. Geol. Surv.*, 1919, pp. 29, 30.

[2] *Ibid.*, p. 31.

[3] *Ibid.*, pp. 30, 31.

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Older Andalusite-Schists are poor within the aureole of the Insch Mass, but such as do occur point, though somewhat indefinitely, to a superimposed metamorphism.

(2) Revision of Carboniferous areas.

Ayrshire and Renfrewshire.

A considerable area of the 'Clyde Plateau Lavas' of Sir Archibald Geikie's classification[1] has been revised during 1919. Mr. Richey has worked on an anticlinal belt reaching north-east through Beith, separating the Ayrshire from the Renfrewshire Coalfields, and also on exposures connecting Dunlop and Busby. He has found in this region a persistent top group of microporphyritic basalts of Dalmeny type, accompanied by subordinate macroporphyritic flows, as for instance at Busby. Mr. Bailey has taken up the mapping from Lochwinnoch to the Clyde, on the west side of the Renfrew basin, and has followed this top group in strong development until, about three miles north-east of Bridge of Weir, exposures fail. It is in keeping with Mr. Anderson's[2] earlier work in the Cathkin Hills, east of Busby, that the Dalmeny type, so characteristic in Fife and the Lothians of Geikie's "puy" eruptions, should here enter largely into the constitution of the Clyde Plateau.

Beneath this persistent group of Dalmeny basalts the sequence is more variable. In the Beith anticline Mr. Richey has mapped a thick succession of macroporphyritic basalts of Dunsapie and Markle types, with an intercalation of Dalmeny flows exposed at Rowbank Reservoir and again (probably) west of Neilston. Between Lochwinnoch and the Clyde also, Mr. Bailey finds macroporphyritic basalts in this position, but in their downward continuation these basalts are interbedded with conspicuous mugearites.

Finally south-east of the Beith anticline Mr. Richey observes that the Dalmeny group is separated from underlying macroporphyritic basalts by well-characterised local zones as follows—

(*a*) East of Neilston: mugearites with small felspar-phenocrysts.

(*b*) Half way between Neilston and Dunlop: microporphyritic basalts of Jedburgh type replacing (*a*).

(*c*) North of Dunlop: mugearites (distinguishable from (*a*)) and other trachydolerites, along with Jedburgh basalts (the southern continuation of (*b*)). Trachyte-lavas (20059, 20093, 20102, 20192) and keratophyre (20193) also occur, but their field-relations to other groups have not as yet been definitely fixed.

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[1] A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. i, 1897, p. 368.

[2] E. M. Anderson in 'The Geology of the Glasgow District,' *Mem. Geol. Surv.*, 1911, pp. 102–104.

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Great petrological interest attaches to the Dunlop district. The Calciferous Sandstone lavas of East Lothian, long ago described by Dr. Hatch,[1] include a varied assemblage of trachytic lavas, but, except for minor occurrences in Bute,[2] similar lavas have not hitherto been recorded from the Clyde Plateau, though intrusions of the type are well known. Another link between Dunlop and East Lothian is the presence of hornblende trachydolerites (20060, 20101) recalling kulaite[3].

With the lavas just described, Mr. Richey has mapped a number of volcanic plugs. Of these, two may be selected for mention—(1) a large twin plug of trachyte, two miles north-east of Beith, and (2) a ring-dyke of gabbro surrounding and chilled against an intrusive complex of macroporphyritic basalt, a quarter of a mile east of Greenside Farm, half way between Beith and Neilston. The rocks of the Greenside complex show interesting pneumatolytic effects with the production of albite and epidote. The ring-dyke itself is of unusually small dimensions. Its interior diameter varies from about 150 to 220 yards, and its annular breadth some 30–60 more. It seems feasible to suppose that vertical movement of the earlier central plug resulted in a surrounding cavity which was filled by uprising gabbro-magma.

In the district mapped by Mr. Richey, the Calciferous Sandstone sediments, immediately above the lavas, consist essentially of volcanic detritus of various degrees of coarseness and usually red in colour. These red sediments are fairly rich in iron oxide, as a rule in small scattered grains, but sometimes in definitely oolitic bands.

The lavas below the detrital zone have been rotted by contemporaneous subaerial weathering, as in the case of the top lavas of the Millstone Grit[4] in the same neighbourhood described in Summaries of Progress (*Mem. Geol. Surv.*) from 1913 onwards. Unfortunately valuable beds of fireclay do not seem to have resulted, although the decomposition of the lavas has often proceeded so far as to render it difficult to distinguish the product from some fine marly sediment. Pseudo-stratification has been developed through the flattening of particles during the process of decay; and sometimes it is only the recognition of amygdaloidal structure, or the association with less rotted kernels, that betrays the igneous origin of the resultant clay.

A fine section is seen in Yardfoot Burn, two miles north of Beith. Here it is plain that the weathering has been volcanic as well as post-volcanic in date. The tops of successive flows

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[1] F. H. Hatch, 'The Lower Carboniferous and Volcanic Rocks of East Lothian,' *Trans. Roy. Soc. Edin.*, vol. xxxvii, 1892, p. 119. E. B. Bailey in 'The Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 127.

[2] H. J. Seymour in 'The Geology of North Arran, South Bute and Cumbraes,' *Mem. Geol. Surv.*, 1903, p. 176; and W. R. Smellie 'The Igneous Rocks of Bute,' *Trans. Geol. Soc. Glasgow*, vol. xv, pt. III, 1916, p. 353.

[3] E. B. Bailey in 'Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 125.

[4] 'Summary of Progress, 1918,' *Mem. Geol. Surv.*, 1919, p. 22.

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have been rotted by weathering, while the lower portions have been less altered.

East of Barrmill, two miles south-east of Beith, a still more striking demonstration of inter-volcanic weathering is afforded by thick beds of sediment in association with rotted flows some distance down in the lava-sequence. In the Lugton Water, for example, a completely rotted porphyritic basalt is succeeded by perhaps 40 ft. of volcanic detritus with subordinate entomostracan shales, and this is definitely overlain by a series of hard unaltered lavas of the top Jedburgh-Dalmeny groups.

In the part of the ground mapped by Mr. Bailey, the only good section illustrating the phenomena of weathering just described occurs along the course of the Gryfe Water at Bridge of Weir.

Economics.—Beds of oolitic ironstone have been mentioned above by Mr. Richey as occurring in the detrital zone overlying the Calciferous Sandstone lavas. They are exposed at two localities:—

(1) Gunshill Burn, 350 yards S.S.W. of Holehouse Farm, 1¼ mile S.S.W. of Dunlop. Thickness perhaps a few feet.

(2) Yardfoot Burn, 350 yards S.W. of Yardfoot Farm, 2 miles N.N.E. of Beith. Thickness, 2 ft. 6 in.

In the hand-specimen the rock consists of ooliths of hæmatite set in a fine-grained buff-coloured ground-mass. The proportion of ooliths to ground mass is about 1:1. The ooliths vary in size from small round grains up to nodules half an inch in diameter. Under the microscope (20027, 20079) they often show concentric growth-bands, where besides hæmatite some foreign matter can be recognised. The ground-mass is composed of detrital material with many quartz-grains, and is relatively poor in iron.

Analyses of material from Yardfoot have been kindly supplied by Mr. J. Gibson, of the Glengarnock Iron Works:—

	Nodules only. per cent.	Sample of Seam. per cent.
Iron	56·64	25·34
Insoluble Residue	9·7 (including 6·9 silica)	48·50

The insoluble groundmass robs the deposit of any present value.

Small concentrations of iron are also met with in connection with the Calciferous Sandstone basalt lavas rotted *in situ*. Specimens were collected from a pocket at the top of a rotted lava-flow in a railway-cutting on the Glasgow and Kilmarnock Joint Railway, ½ mile E. of Barrmill Railway Station. For this Mr. J. Gibson kindly supplies the following analysis:—

	per cent.
Iron	36·14
Insoluble Residue	34·40 (including 19·00 silica)
Sulphur	0·144
Manganese oxide	0·18
Lime	0·25
Loss on ignition	7·70

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In this case again the high percentage of insoluble residue makes the deposit valueless.

Glacial.—Mr. Bailey finds that the merging of the high lava-country south of the Clyde estuary into the lower sedimentary territory farther east is accompanied by interesting glacial characteristics. Between the drift-free high ground and the more or less completely covered low ground there lies, at intermediate elevations, a certain amount of boulder-clay, everywhere disposed, between the Clyde and Bridge of Weir, in the form of isolated drumlins. These drumlins often stretch athwart the scarp-and-hollow featuring of the lavas they surmount. They commonly attain to 50 ft. in thickness. At the same time drumlins are by no means restricted to the intermediate belt; they are characteristically developed in the boulder-clay spread on the lower ground farther east.

Now the driftless nature of the high ground is probably connected with the rapid movement of the ice where it hurried forward, making up in pace for what it lacked in depth. We may take it then that the ice farther east was also moving rapidly, though not so rapidly as to preclude the deposit of boulder-clay. The drumlin form of the boulder-clay, manifest, as it is, in the first appearance of the deposit, favours one of two alternative suggestions. The discontinuous ice-motion, of which the drumlins are a register, may be:—

(1) A feature of a rapidly moving ice-sheet as such, or

(2) A feature of a rapidly moving ice-sheet where motion comes to be checked by increasing depth.

Of these the former seems perhaps more consonant with evidence from other quarters.

It should be remarked that the particular drumlins upon which the above conclusions are based, are not mere variants of crag-and-tail phenomena.

Farther south in the upland district extending to the east of Beith, the original survey demonstrated that the main glaciation came from the north rather than the south. During the present revision Mr. Richey has obtained abundant confirmatory evidence of this, including striated *roches montonnées* moulded by ice from north-east to south-west.

At Lugton, about four miles east of Beith, Prof. Gregory[1] has advanced evidence suggesting glaciation from S.W. to N.E. The glaciated surfaces seen by him have since been removed, but some 20 yards away in the same quarry there is now exposed indisputable evidence of glaciation from N.E. to S.W. The limestone quarried has an irregular top on which rests a bed of fireclay. This top has yielded during glaciation a number of miniature striated *roches montonnées*, of which the orientation is clearly defined.

[1] J. W. Gregory, 'Glaciated Rock Surface at Lugton, North Ayrshire,' *Trans. Geol. Soc. Glasgow*, vol. xiii, pt. 1, 1907, p. 10.

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No additional area was revised during 1919 in the Central Coalfield, except that the igneous rocks described by Mr. Bailey and Mr. Richey to some extent enter into the marginal six-inch sheets on the west side of the coalfield around Paisley and Bridge of Weir. The revision of that coalfield is now completed so far as the coal-bearing strata are concerned, but considerable areas of the non-productive strata around the field require revision in order to complete the one-inch sheets; this is especially the case in South Lanarkshire (one-inch Sheet 23), of which about a half is as yet unrevised. The coalfields adjacent to the Central Coalfield now call for attention. Mr. Dinham has been at work in the district between Stirling and Denny and has paid special attention to the Lower Limestones, which are excellently exposed in the valleys of the Carron and the Bannockburn. Mr. H. H. Read has begun the revision of the Alloa Coalfield, which, occupying a position between the Fife Coalfield and the great Central Coalfield, forms an important connecting link and requires careful study, especially as regards the sequence and correlation of seams.

Douglas Coalfield.

In the Douglas Coalfield in South Lanarkshire which was being revised before the outbreak of war, no additional area has been revised, but the cores of many of the new bores now in progress have been examined by Mr. Macgregor and the correlation of the seams with those of the other coalfields of Lanarkshire and Ayrshire has been considered. Some of Mr. Macgregor's results are embodied in the following report.

During the past year our knowledge of the Carboniferous formation as developed in the important outlier of the Douglas Coalfield has been considerably increased, and more especially in regard to the Carboniferous Limestone Series. It has been possible, for example, to recognise in the Douglas area horizons which are well-known in the Central Coalfield, and to establish a definite correlation of the Coalburn sequence with that found to the north of the broad barrier of Old Red Sandstone rocks which stretches from Lesmahagow to Lanark. The discovery of *Posidonomya corrugata* in the limy shales immediately underlying the Top Macdonald Limestone, renders the correlation of the Macdonald Limestones with the Hosie Group a matter of certainty. Probable representatives of the Under Limestone and of the Basket Shell-bed of the Strathaven district have also been recognised. Attention has naturally been paid chiefly to the Limestone Coal Group, and the most striking feature it displays in this area is its great variation in thickness. In the Coalburn field, on the west side of the basin, it is from 55 to 66 fms. thick and is probably even less than this below the Millstone Grit of the Poneil area, but where it reappears at the surface on the east at Ponfeigh and Rigside it is nearly twice as thick. The increase is distributed throughout the whole sequence and affects barren strata and coals alike. The latter vary in thickness through-

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out the field, but are unquestionably thicker and more numerous on its eastern margin. The sections given in Fig. 1 bring this out clearly and show in addition the correlation of the seams wrought at Coalburn and at Ponfeigh. In establishing the correlation two thin blackband ironstones have proved of significance; the lower of these—above the Nine-foot at Coalburn and above the Kirkroad at Ponfeigh—is the more persistent and was formerly much wrought. These blackbands are sometimes developed merely as a few inches of irony parrot, but can generally be recognised on careful examination. The upper part of the sequence is in some cases interrupted by the occurrence of coarse gritty sandstones which cut out and replace one or more of the coals. So far as is known these are of local occurrence and the phenomenon is probably analogous to the 'wash-outs' found at Bankend and Dalquhandy in the workings of the Nine-foot Coal.

The sequence at Coalburn is similar to that found in the Muirkirk-Glenbuck area, and the names given to the chief coal and limestone horizons are for the most part common to the two fields. At Ponfeigh and Rigside, on the other hand, a local nomenclature is in use (*see* Fig. 1). The marine band that occurs some 7 to 16 fms. above the Top Macdonald (or Top Hosie) Limestone has been noted in many borings and forms a useful index-mark in obscure ground. It consists of 5 or 6 ft. of shelly impure limestone or limy fakes and corresponds to the well-known Johnstone Shell-bed of North Ayrshire and the Central Coalfield. Over the latter it has been traced from Paisley and Glasgow as far north as Denny and as far east as Bathgate and Wilsontown. The 'Black Metals' of the Central Coalfield are represented by the 4 or 5 fms. of black shales (blaes) containing nodules and thin ribs of clayband ironstone which occur between the Six-foot and Nine-foot Coals or, in the Ponfeigh sequence, between the Stony and Robb seams. The only fossils obtained as yet at this horizon are a few specimens of *Lingula* and in this the Douglas area agrees with the Glasgow and North Ayrshire districts, although at many places east of Glasgow—e.g., at Denny, Bathgate, Wilsontown, Carluke, East Kilbride, etc.—a definitely marine band is found in the 'Black Metals.' The associated claybands were formerly wrought to some extent at Bankend and Auchlochan, but are generally poorly developed in the Douglas field; they correspond to the Logan's Bands of Ayrshire, the California and Banton Claybands of Glasgow and Kilsyth respectively, the Hogg Fence Ironstones of Wilsontown and the Maggie Bands of Carluke, and occur upon the same horizon as the High-band and Mid-band Ironstones at Muirkirk. The coal which commonly underlies this series in the Douglas field is the equivalent of the Thirty-inch of Muirkirk and is wrought at Douglas Colliery under the name of the Back Seam; its equivalent in the Central Coalfield is no doubt the Upper Garscadden Blackband or the thin coal which so frequently takes the place of the latter. The Six-foot coal of Coalburn (or its equivalent, the Robb and Fallowhill of Ponfeigh) represents the Lesmahagow Main Gas,

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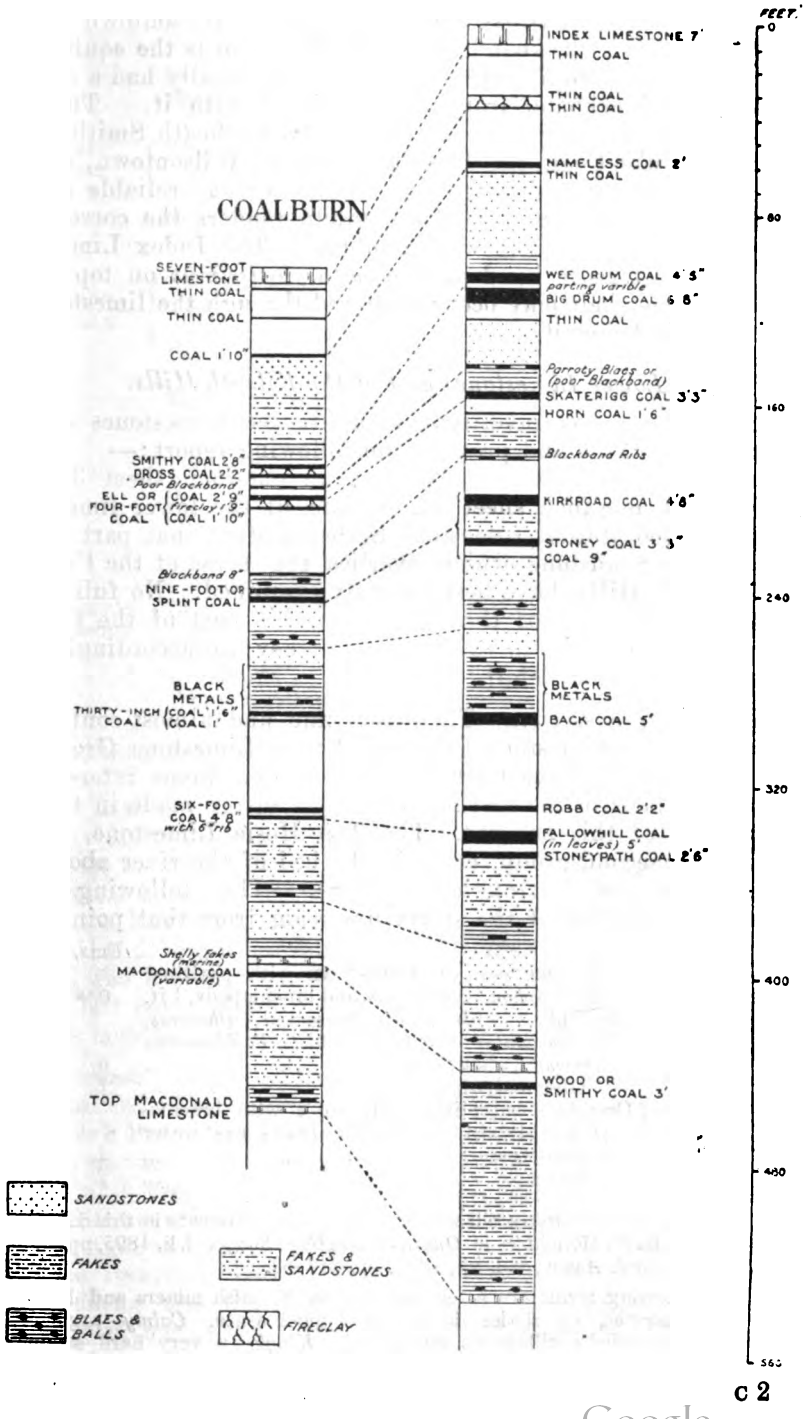
FIG. 1.—COMPARATIVE VERTICAL SECTIONS OF THE DOUGLAS COALFIELD.



C 2

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or Wilsontown Gas, Coal, and at Muirkirk is known as the Catchyburn. Both it and the Nine-foot above it contain ribs of cannel. The latter seam is apparently represented at Ponfeigh by two coals, the Kirkroad and the Stony, and corresponds to the Auchenheath Dross, Carluke Tower, or Wilsontown Main, Coal. The thin blackband above the Nine-foot is the equivalent of the Auchenheath Wee Gas Coal, which generally had a 3 to 5-inch rib of blackband ironstone associated with it. The Ell Coal again is possibly the same as the Auchenheath Smithy, the Lower Carluke Coal, the Fireclay Craw of Wilsontown, or the Jewel of Bathgate, although the absence of any reliable index-horizon in the upper part of the group renders the correlation of the higher seams somewhat doubtful. The Index Limestone has a characteristic band of *Productus latissimus* on top of it, and the same shell may occur scattered through the limestone or immediately below it.

Lower Limestones east of the Kilsyth Hills.

Mr. Dinham has investigated the Lower Limestones of the Bannockburn area and presents the following report:—

In the district between Bannock, in one-inch sheet 31, and Stirling, in one-inch sheet 39, sections of the lower limestones of the Carboniferous Limestone Series, and of that part of the Calciferous Sandstone which overlies the lavas of the Campsie and Kilsyth Hills, have been recently examined. No full report of the development of these strata in this part of the Central Valley appears to be in existence, and they are accordingly now described in some detail.[1]

River Carron section.—There is a fine and almost continuous section of the Limestone Coal and Lower Limestone Groups in the north bank of the Carron above Denny. Some reference to particular beds in the first-mentioned group is made in the last paragraph of this account. The Top Hosie Limestone, at the top of the second group, crops in the bed of the river about 170 yards west of Carronglen Cottage. The following is a generalised section of the strata upstream from that point:—

		Fms.	ft.	in.
Top Hosie.	Dark blue calmy[2] LIMESTONE with pyritised '*Bellerophon*,' *Naticopsis*, and brachiopods, 1 ft.	0	1	0
	Blue blaes with poorly preserved *Orthoceras*, *Sanguinolites costellatus*, and ? *Posidonomya corrugata*, about 4 ft.	0	5	0
	Obscured, about 5 ft.	1	4	0
Second Hosie.	Grey-blue encrinital LIMESTONE with brachiopods, at least 14 in. (visible only at lowest water in mid-stream)	1	5	2
	Obscured, about 2 ft....	2	1	2

[1] Accounts of the Stirling Sill and of some of the sediments in this district are given by Mr. H. W. Monckton in *Quart. Journ. Geol. Soc.*, vol. li, 1895, pp. 480–92, and in *Proc. Geol. Assoc.*, vol. xii, 1892, pp. 242–53.

[2] The following terms are in current use by Scottish miners and borers:—*Blaes*—mudstones, or shales in the geological sense. *Calmy*—argillaceous. *Fakes*—thin-bedded argillaceous sandstone. *Kingle*—a very hard sandstone, often with a limy cement. *Rib*—a thin layer. *Plies*—thin bands.

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		Fms.	ft.	in.
	Hard black sandstone, flaggy at top, about 29 ft.	7	0	2
	Fakes and fireclay, with thin coaly streak, 8 ft. ...	8	2	2
	Kingle with plant-remains, and markings like *Spirophyton* on its upper surface, 2 ft. ...	8	4	2
	Micaceous blaes, with a 3-in. band containing *Aviculopecten, Sanguinolites, Streblopteria*, etc., 1½ ft.	8	5	8
	Fakes and fireclay, 2½ ft.	9	2	2
	Blue blaes with irony ribs and *Orthoceras*, '*Bellerophon*,' and lamellibranchs, 5 ft. ...	10	1	2
? Main Hosie	Grey sandstone, locally ochreous, with encrinites, etc. (probably a decalcified LIMESTONE), 2 ft.	10	3	2
	Obscured, about 5 ft.	11	2	2
	Sandstone and fakes, about 22 ft.	15	0	2
	Dark-blue blaes, faky at top, (under water) ? barren, about 12 ft.	17	0	2
Carron Kingle	Blue limy kingle, weathering like a limestone, with fish-teeth and ? entomostraca; no marine fossils, about 2 ft. 4 in.	17	2	6
	Fakes with sandstone-ribs, passing down into fakes, about 35½ ft.	23	2	0
	Light-blue faky blaes, with white worm-casts, a few marine fossils at the top, 6 ft.	24	2	0
	do. with pyritous pellets and rare encrinites, 26 ft.	28	4	0
	Hard blue flaggy fakes, 2 ft.	29	0	0
	Light-blue faky blaes, with pyritous pellets, and irregular rusty pyritous nodules increasing in size and number towards the base. Encrinites common at the very bottom, 20 ft.	32	2	0
Fankerton Limestone	LIMESTONE with indistinct encrinites, grey and greenish, 2 ft.	32	4	0
	Hardened grey blaes, about 1 ft....	32	5	0
	LIMESTONE, grey and blue, 2 ft. 6 in.	33	1	6
	White crystalline hardened sandstone, about 10 ft.	34	5	6
	Inaccessible, about 6 ft.	35	5	6
	Top of big dolerite-sill	–	–	–

The last-mentioned strata are marmorised and otherwise intensely altered by the underlying intrusion. This sill, which 1½ miles to the north-east is known to be at least 280 ft. thick, continues upstream in the sides of the river until it meets the Campsie Fault, or its continuation, about 150 yards east of a sharp bend below Garvald Mills. There it is thrown altogether above the low right bank, but appears at the very top of the steep left bank, where isolated exposures of ashy sandstones and shales may be seen between it and the Calciferous lavas beneath.

Bannock Burn section.—The strata described in the generalised table which follows, crop out in the valley of the Bannock Burn, 4 to 5 miles S.S.W. of Stirling and about 4 miles N.W. of the Carron section. The greater part is exposed in the bank and bed of the stream about a mile S.W. of the North Third Reservoir of the Grangemouth Water Works; the highest beds, however, are seen only in the (south) Sauchie Craigs east of the reservoir, being cut out at the other exposures by the descending base of the sill which forms the Craigs. This intrusion, like that of the bottom of the Carron section, is a continuation of the Stirling Castle and Abbey Craig Sill.

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		Fms.	ft.	in.
Bottom of dolerite-sill		–	–	–
	Pale-blue blaes, altered near the sill, with numerous pyritous pellets; larger irregular pyritous nodules near the base; occasional encrinites at the bottom, up to 26 ft.	4	2	0
BANNOCK "A" & "B" LIMESTONES.	Blue partly decomposed encrinital LIMESTONE, 2 ft. 6. in	4	4	6
	Barren blue blaes, 1 ft. Obscured strata, 1 ft. ...	5	0	6
	Blue LIMESTONE with mottled fracture; irregular 'ooliths,' up to more than an inch in diameter, show on the weathered surface. No marine fossils seen. 1 ft. 7 in.	5	2	1
	? Sandy marl, or decomposed dolerite ? 2 ft. 6 in.	5	4	7
	Greenish baked nodular fireclay ?; locally fakes with some blaes, 5 ft. 8 in.	6	4	3
	Sandstone (locally a ganister) and fakes 4½ ft. ...	7	2	9
	Blue crumbly blaes, apparently barren, 6 ft. ...	8	2	9
	Sandstone-posts and ribs, with fakes, 9 ft. ...	9	5	9
	Blue blaes with traces of plants, 1 ft. 6 in. ...	10	1	3
	Black platy blaes, with athyrids, productids, *Lingula*, and a lamellibranch, 4 in.	10	1	7
BANNOCK "C" LIMESTONE	Hard blue encrinital LIMESTONE decalcified, with abundant marine fossils at top and bottom, 3 ft. 5 in.	10	5	0
	Bright COAL 5 in., on soft fireclay 5 in.	10	5	10
	Rubbly sandstone, and sandstone fakes, 19 ft. ...	14	0	10
BANNOCK "D" LIMESTONE	(Obscured by old workings, which extend along the whole length of the sections, 16 to 20 ft.)	17	0	10
	Blaes with small crystals of gypsum, 2 ft.. ...	17	2	10
	Blaes with regular pyritous ribs, 3 ft.	17	5	10
	Blaes with gypsum, 1 ft. 2 in.	18	1	0
	Papery blaes with strongly curved bedding, 1 ft....	18	2	0
	Blaes with lenticles of clayband ironstone; entomostraca and fish-teeth at base, 1 ft. 8 in.	18	3	8
	Blaes with 3 in. limy clayband and occasional marine fossils, 1 ft. 9 in....	18	5	5
BANNOCK "E" LIMESTONE	White and yellow LIMESTONE:—nodular with large encrinites, and coaly films at top, 2½ ft.; more nodular, with lamellibranchs, gastropods, *Fenestella*, rod-like bryozoa and a doubtful coral, 2 ft.; faky and nodular, 1 ft. Total 5½ ft.	19	4	11
	Blaes and limestone-bands, with brachiopods, 2 ft.	20	0	11
BANNOCK "F" LIMESTONE	Grey slabby LIMESTONE, composed of harder and softer bands. Top 3 in. locally slightly nodular, remainder very fossiliferous (encrinites, *Archaeocidaris*, *Tabulipora scotica*, and brachiopods. No corals noticed), 2 ft. 2 in.	20	3	1
	Blue micaceous blaes with a 6-in. clayband. *Lingula* and fish-remains locally, 2 ft. 2 in. ...	20	5	3
	Ashy marl or mudstone (locally blaes with plant remains), 1½ to 3 ft.	21	1	6
	Ashy sandstone often quite green, hard or soft, 3 to 6 ft.	21	5	6
	Ashy fakes and blaes (locally a coarse detrital ash), with ashy sandstone-ribs at bottom, 7 to 9 ft.	23	1	6
	Blue thin blaes, apparently barren; ribs of fakes and ? pyritous ironstone in bottom half. 13½ ft.	25	3	0

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		Fms.	ft.	in.
Bannock "G" Limestone	Limestone: faky, with exceedingly abundant fossils, including giganteid *Productus*, *Lithostrotion* and a clisiophyllid coral, 3 in.; compact, locally lenticular, with brachiopods, 6 in.; faky, with abundant fossils (encrinites, brachiopods, large productids lying on their ventral valve, '*Euomphalus*,' lamellibranchs, and a zaphrentid coral), 9 in. Total, 1 ft. 6 in. ...	25	4	6
	Blue blaes, partly ashy; at base a thin layer of ? mother-of-coal with cone-in-cone structure, 2 ft.	26	0	6
	French-grey mudstone or ashy marl, 1½ to 3 ft. ...	26	3	0
	Line of discordance.			
	Bedded variegated detrital 'ash,' with nodules of hard chocolate 'marl'; the beds are clearly truncated by the overlying stratum, about 20 ft.	29	5	0
Lavas of the Kilsyth Hills		–	–	–

The Bannock "D" Limestone must be the "Murrayshall Limestone" formerly wrought at Cambusbarron, 1½ miles W. of Stirling, at Murrayshall, 2 miles S.W. of Stirling, and at Craigend and Touchadam, north of the Reservoir. No section of this seam or of the adjacent strata is now exposed, but according to a century-old record[1] the limestone at Murrayshall was a bluish-black seam 6 ft. thick, with "entrochi" (encrinites) and specks of pyrites, lying in the middle of not less than 35 ft. of dark blaes, partly limy at the bottom. A 3-ft. limestone, 42 ft. above the main seam, rested on 4 ft. of blaes mixed with coal, and thus appears to correspond to "C," the only limestone beneath which a coal has been noticed.

Correlations.—Comparison shows that the above sections cannot be matched with each other, except that the Fankerton Limestone of the Carron resembles the Bannock "A" and "B" Limestones taken together. The intense alteration produced by the intrusion prevents a detailed comparison of the beds, but in each case we have two limestone-seams separated by a foot or so of blaes, lying above more or less sandy strata and beneath several fathoms of blaes which, alike in thickness and in the lithological peculiarities described, differs from any other beds of blaes in the sequence at either place. It is accordingly natural to consider these limestones as equivalent, and this identification leads to consistent results.

In correlating these exposures with the sections at Campsie and Kilsyth, there can be no doubt that the two highest Carron Limestones are the Top Hosie and the Second (or Mid) Hosie[2]. The decalcified limestone in the Carron may be the Main Hosie of the Hurlet District, formerly seen (now quarried away), also in the Burniebrae Burn ("Shields Burn"), Campsie, east of Shields steading, at a horizon about 4 fms. below the Second Hosie. The thick blaes above the Fankerton Limestone resembles that

[1] Lt.-Col. Imrie, *Mem. Wernerian Soc.*, vol. ii (1818), pp. 28, 34, 50, and plate.

[2] Together, the 'Hosie Limestone' (in 2 beds) of Macnair and Conacher, *Trans. Geol. Soc. Glasgow*, xv, part i, (1912–13), pp. 43 and 48, and the Bellerophon, or Hosie, Limestone of 'The Geology of the Glasgow District,' *Mem. Geol. Surv.*, 1911, p. 24.

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which overlies the Blackhall[1] at Corrie and in the lower part of the Burniebrae Burn. As Mr. Carruthers points out, the non-marine, "oolitic," nature of the Bannock "B" Limestone is exactly comparable to that of the lower part of the Blackhall Limestone[2], an observation which confirms the conclusion already reached as to the identity of the Fankerton with the Bannock "A" and "B" Limestones. Limestone "C" will then represent the sandy encrinital limestone of Campsie[3], and "D" will be the Hurlet, so that the prevailing identification of the latter with the Murrayshall Limestone remains unchanged. Certain resemblances between the remaining Bannock Limestones and the Corrie section at once suggest themselves; whether the differences from both Corrie and Touchadam (*see below*) are due to lateral variation, to local unconformity, or to both causes combined has yet to be investigated, but the following remarks, extracted from a report by Dr. G. W. Lee on the fossils recently collected from the Bannock section, must be taken into consideration in any correlation.

(1) Blaes below Limestone "D."—These beds contain abundant *Sanguinolites costellatus*, with *Myalina verneuili*, *Euphemus urei*, and a goniatite—all members of the "Abden Fauna," below the Hurlet Limestone.

(2) Limestone "E."—This bed also contains *Productus pugilis* in abundance, *Productus youngianus*, and bands of Bryozoa (*Rhabdomeson*). These faunal characteristics are strongly marked in the White Coral Limestone (to the exclusion of other horizons) at Corrieburn, a seam which the Bannock "E" Limestone closely resembles also in general aspect. All the palæontological and lithological evidence points to the equivalence of these two limestones.

(3) Limestone "F."—There is nothing distinctive in the fauna of this limestone.

(4) Limestone "G."—This is characterised by the abundance of giganteid *Producti*, which, with single and compound corals (*Syringopora*, *Lithostrotion*, *Diphyphyllum*) and other fossils, constitute an assemblage quite typical of the Hollybush limestone fauna, as represented in the Survey collections from the Hollybush district. There is nothing like it in the Corrieburn section.

One result of the above comparisons is that, the Fankerton Limestone being no longer regarded as the Hurlet, the consequent absence of the true Hurlet and of the lower seams from the Carron Section is to be ascribed to faulting, as already mentioned, probably combined with a descent of the sill, on the

[1] Blackhall Limestone, Glasgow *Memoir*, pp. 22–24; Baldow Limestone of Macnair and Conacher, *loc. cit.*, p. 46; Black Limestone or 'Hosie Limestone' (of Campsie) in Glasgow *Memoir*, p. 23; in John Young, *Trans. Geol. Soc. Glasgow*, i, 1860, p. 27, and do., 3rd ed, 1894, p. 42; in J. Neilson, *ibid.*, xiv, pt. iii, 1911–12, p. 327 footnote, pp. 328–333; etc.

[2] Macnair and Conacher, *loc. cit.* pp. 46 and 49 ('q'), Glasgow *Memoir*, pp. 23 and 24.

[3] Exposed in Cowies Glen (part of the 'Shields Burn'), *see* Glasgow *Memoir*, p. 23; also in the Baldow Glen, etc. This is the 'Shields Bed' of Macnair and Conacher, *loc. cit.*, pp. 45 and 47. It does not yet appear to have been recorded from Corrie.

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upstream side of the fault, to a lower stratigraphical horizon. The latter phenomenon is suggested by a bore through the sill near Quarter, which reached the lavas without any record of limestones or of more than a few feet of normal clastic sediment.

The Touchadam Section.—Farther down the Bannock Burn, ⅔ mile below the Reservoir, in the stream at Touchadam Quarry, other sections of lower limestones are exposed in a small syncline. They show such differences from those higher up the Burn that they cannot yet be satisfactorily correlated. The Murrayshall Limestone has been taken out both at the quarry and beneath the crags on the opposite side of the stream where, near the old level, and about 5 ft. below the big sill, a 38-in. seam with abundant *Lithostrotion* rests on a thin ashy bed (? white trap) above 18 ft. of sandstone overlying 12 ft. of barren blaes. This appears to be the Bannock "C" Limestone. Below the Murrayshall Limestone, of which numerous fragments remain in a waste-heap in the quarry, the following sequence can be made out:—

		Fms.	ft.	in.
Murrayshall Limestone		–	–	–
	? Gap., 0 to about 19 ft.			
	Blaes with *Lingula* and entomostraca, 6½ ft. ...	1	0	6
	Black blaes with fireclay and thin ribs, uneven bedding, 11 in.	1	1	5
	Blaes with *Lingula* and a small lamellibranch, 1 ft. 2 in.	1	2	7
	Fireclay and blaes, 9 in.	1	3	4
	Slaty blaes with *Orthoceras*, goniatites, *Euphemus*, *Sanguinolites costellatus* and entomostraca, 1 ft. 4 in.	1	4	8
	Softer blaes with similar fossils: ironstone-ribs with entomostraca near bottom, 3 ft.	2	1	8
	Blaes with *Lingula*, entomostraca, and two crystalline LIMESTONE ribs, 2 ft. 4 in.	2	4	0
	Pale variegated marls and ashy mudstones with limy nodules, 27 ft.	7	1	0
	Blaes with *Lingula*, 1 ft. 10 in.	7	2	10
GONIATITE-LINGULA LIMESTONE	Slabby LIMESTONE and limy blaes with abundant goniatites and *Lingula*; *Orthoceras gesneri*,[1] lamellibranchs, and fragments of brachiopods. Two ribs of encrinital limestone below the middle, 4 ft. 2 in.	8	1	0
	Blaes with gypsum-efflorescence, pyritous rib near base, 7½ ft.	9	2	6
	Pale marl or ashy mudstone, 9 ft.	10	5	6
	Obscured, about 10 ft.	12	3	6
	Blaes and faky blaes, more or less ashy, about 13 ft.	14	4	6
PRODUCTUS LIMESTONE	LIMESTONE and limy blaes with abundant large *Productus*, about 3 ft.	15	1	6
	Pale ashy blaes, up to 2 ft.	15	3	0
	Bedded chocolate and green 'ash' and marls, ? 30 ft.	20	3	0
Lavas		–	–	–

[1] A rare fossil recorded previously in Scotland at South Cobbinshaw (from the Raeburn, formerly Mungle, Shell Bed. *See* 'Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 1912, p. 94), and at Craigenglen; also from the Upper Limestone Group.

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The width of the syncline measured between the two crops of the Productus Limestone, is about 150 yards. It is traversed by several small faults, one of which, with a gentle hade and a southerly downthrow of 10 ft., complicates the cliff-section in the left bank, and repeats the crop of the Goniatite-Lingula Limestone in the stream on the southern limb of the fold.

The continuous line of quarries from Touchadam right up to the higher part of the Bannock Burn must surely be in the same seam, viz., the Murrayshall Limestone. If further the Productus Limestone corresponds to "G," the Goniatite-Lingula Limestone to "F," and "E" be represented by part of the 27 ft. of variegated marls with limy nodules, as Mr. Tait suggests, we have then an example of lateral variation which well illustrates the difficulties of correlation among the lower Carboniferous limestones.

Dr. Lee reports that the Goniatite-Lingula Limestone contains a rich assemblage, not represented in the Corrieburn section, which has many points in common with the Basket Shell Bed exposed at Cot Castle near Strathaven. Among these are the abundance of goniatites (including *?Dimorphoceras*), *Orthoceras*, and brachiopods, and the presence of several kinds of lamellibranchs (including *Cypricardella rectangularis*).

Other exposures.—At Old Sauchie, 1½ miles E. of the Reservoir, the Bannock section is seen again, from the blaes above Limestone "A" to the coal beneath "C." One mile W.S.W. of this point, a disturbed section of quarried limestones is seen in a "window" through the dolerite, on the north side of an east-and-west fault which runs along the Auchenbowie Burn. Immediately south of this fault sandstone, and some blaes with marine lamellibranchs, are seen below the sill; but no limestones are exposed, nor are there any lines of old workings to the southward, and it seems probable that, between the Auchenbowie fault and the point where the Campsie Fault crosses the Carron, the dolerite occupies a stratigraphical horizon lower than it does beyond those limits. It is to be noted that it is only within the same limits that there are conspicuous limestone workings *above* the sill, at Northfield and in the burn west of Quarter; these are presumably also in the Murrayshall ("D") Limestone, but there is no definite evidence on this point.

The Top Hosie with *Posidonomya corrugata* is still exposed at the south end of some old workings in the Chough Glen[1], where the Second Hosie was probably taken out at the same time. These two limestones are also exposed in the Castlerankine Burn near Linns[2], while higher upstream and close to the boundary-fault, a different, decomposed seam, may possibly be the Main Hosie. Further down the same burn, about half-a-mile W. of Rashiehill, the Top Hosie is again seen, and 200 yards from the steading a thin band of marine fossils, at the bottom of a small

[1] 'Explanation of Sheet 31,' *Mem. Geol. Surv.*, 1879, pp. 62 and 68, locality 194.

[2] *Ibid.* Locality 185.

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cliff of blaes, is probably the position of the Johnstone Shell Bed[1] which is faulted out of the Carron Section. The marine band in the "Black Metals," at a still higher horizon, is exposed in the Carron opposite the Herbertshire Paper Mill[2]. It consists of 3½ ft. of fossiliferous blaes, and the band of crushed *Naiadites*, found also at other localities a few feet higher in the sequence, is conspicuous at the same spot.

Many bores which are being put down in the coalfields and oil-shale fields have been visited by Dr. Lee. Two recently put down at Blackness, Linlithgowshire, in search of a north-western extension of the oil-shale fields of Linlithgowshire, have shown the absence of workable oil-shale in that district. The sequence is remarkable in the attenuation of the oil-shale strata between the Broxburn and the Pumpherston horizons. Particulars will be found in Appendix II. We are especially indebted to Mr. James Kidd, M.P. for Linlithgowshire, for permission to publish the results of these bores.

(3) Boring for Oil at West Calder.

The bore in search of petroleum which is situated about a quarter of a mile south of the village of West Calder, Midlothian, has now reached a depth of 543 fathoms, and is the deepest bore which has yet been put down in the Oil-Shale Series in Scotland. The West Calder district is included in six-inch Sheet Edinburgh 11 N.W., published in 1908, but of which a new edition is in preparation. A small anticline occurs to the south-west of West Calder and the oil-bore has been placed approximately on the summit of this anticline, which is about half-a-mile in diameter and gives place to synclines on the east and south. The important Calder fault has been traced on the east side of the anticline, but perhaps dies out as it runs south-westwards, as the dislocation of the outcrops of the oil-shale seams cannot be of great magnitude. At a distance of about half-a-mile to the south-west of the bore there are several small faults.

The bore starts immediately below the Broxburn Shale which has been mined to the outcrop a short distance to the west. At a depth of 50 to 55 fms. it passes through an oil-shale which is recognised by the mining engineers of the district as the Dunnet seam. About 73 fms. from the surface there is another oil-shale, which is probably the Under Dunnet, well known in the adjacent district[3], but frequently not of economic value. Thirty fathoms lower down there is a light-brown fresh-water limestone with entomostraca, apparently 10 to 12 ft. thick. This may be the Barracks Limestone, though that bed is

[1] 'Top Marine Band' of P. Macnair, 'The Hurlet Sequence,' etc., *Proc. Roy. Soc. Edin.*, vol. 38, pt. ii, 1917, p. 185.

[2] 'Explanation of Sheet 31,' pp. 62, 68 and 69, locality 192.

[3] 'Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., 1912, p. 21.

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generally not well represented at West Calder. In other respects the upper portion of the bore does not differ from the sections recorded in other bores in the immediate vicinity. The deeper strata, however, have not been proved hitherto by boring at West Calder and the new record is of interest, not only as furnishing evidence of the exact geological sequence, but as differing somewhat from natural exposures in the neighbourhood.

The first recognisable horizon below the Barracks Limestone is the Burdiehouse Limestone, which was 15 ft. thick and was entered at 215 fms. It shows the usual characters, being a dark-coloured, fine-grained, fresh-water limestone. Between these limestones there are 110 fms., mainly sandstone with intercalations of dark shale, but although a thin oil-shale was found at 188 fms., there is no indication of any deposit of economic interest, and in the Camps Shale position above the Burdiehouse Limestone nothing of value was met with. For 63 fms. below the Burdiehouse Limestone there was a rather monotonous sequence of dark carbonaceous shales with a few beds of sandstone near the top, some marls and a thin dark limestone.

At 280 fms. a thick bed of greenish volcanic ash was encountered and this persisted to a depth of 418 fms. As a whole this ash-bed was uniform in composition, but occasionally it had an admixture of dark shale and at 375 fms. the rock-powder extracted from the bore showed traces of coal. The larger fragments in the ash were examined microscopically and proved to be olivine-basalt. From 418 to 433 fms. the bore passed through black shales, with a thin non-fossiliferous limestone of the type known in this district as a 'cement.' There another basaltic ash-bed was proved which persisted from 433 to 489 fms. Apparently it was free from admixed sediment. Below this there were 7½ fathoms of vesicular dark-green olivine-basalt, in a single lava-flow so far as was ascertained. From the base of this lava at 497 fms., black shales with a few thin seams of limestone or 'cement' extend to the bottom of the bore, a farther depth of 46 fms. The distance below the base of the Burdiehouse Limestone (217 fms.) is at present 326 fms., and is almost entirely occupied by black shales, basaltic ash-beds, and one lava-flow. None of the oil-shale seams that lie below the Burdiehouse Limestone, such as the Pumpherston, Dalmahoy, Wardie and Coalheugh Shales have been identified, but this was not unexpected as in no part of the surrounding country have they proved to be workable.

From a geological standpoint the striking feature of the bore record is the general character of the sequence below the Burdiehouse Limestone. In the nearest available section, that seen in the Murieston Water from Harburn to Skivo (from 2 to 4 miles distant) the sequence at this horizon consists largely of sandstone, with one oil-shale (the Coalheugh Shale), a limited amount of black carbonaceous shale and probably a few insignificant ashy beds[1]. Three miles to the south, in the Cobbin-

[1] 'Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., 1912, p. 27.

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shaw district, these lower beds have been proved by bores and are visible in natural exposures. In that district the Pumpherston Shales are not workable, but there is a bed of volcanic ash, known as the Crosswood Ash, which may be on the same horizon as that which occurs in the West Calder bore. It is only 7 fms. thick, while in the bore under discussion there are 194 fms. of basaltic ash. At Crosswood also there is no lava-bed below the ashes. Other points of difference are that in the Cobbinshaw area there are frequent deposits of sandstone and shaly sandstone, a few thin encrinital limestones and intrusive sills of dolerite among the strata below the Burdiehouse Limestone, all of which are absent at West Calder, so far as the bore has yet proved.

III.—PETROGRAPHICAL WORK.

The work carried out in the Petrographical Department during the past year has been mainly connected with the preparation of a memoir on the petrography and chemistry of certain refractory materials, which is now in the press. Dr. Thomas has continued his work for the Research Department of the Admiralty and has reported upon matters of economic importance to Government departments and many private individuals. At the request of the Home Office, he furnished reports upon the microscopical and mineralogical characters of dust aspirated under special conditions from ganister-mines and other underground workings, after examination of some 50 samples.

The petrographical work connected with the survey of the Island of Mull, Moor of Rannoch and Ayrshire has been continued, and the study of the interesting xenolithic and sapphire-bearing composite sills of Mull has been resumed.

The petrography of the igneous rocks of Croft and adjoining areas has been undertaken by Mr. Whitehead for the memoir on the New Series Sheet 169 (Coventry).

The detailed petrography of Sheet 86, Scotland, is being dealt with by Mr. Read, and considerable progress has been made.

IV.—CHEMICAL WORK.

With reference to the work done in the laboratory, Mr. Ennos reports that the analyses of silica rocks and dolomites referred to in last year's 'Summary of Progress,' have been incorporated in 'Special Reports on the Mineral Resources of Great Britain,' Vol. XVI, which is now in the press. The analysing of a series of fireclays, 12 of which have been completed, has been commenced for another volume of these reports. Partial analyses of four iron-ores were made for Vol. XII of the reports, which deals with the iron-ores of Mesozoic and later formations. Three Scottish rocks previously examined for alkalis only, and a mineral from Ayrshire approximating in composition to kaolinite, have been analysed with the following results:—

Tourmaline-granite (pegmatite).—Vertical dyke in schists. Banffshire coast, west side of East Head, three-quarter mile

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north-east of Portsoy. One-inch sheet 96. Six-inch Banff. 4 N.W.

Slice No. S. 19628. Lab. No. 550.

Felspar-rock.—Vertical dyke, intrusive in Lewisian gneiss. Roadside at Cnoc an Tuir, halfway between Rhiconich and Achriesgill, north-eastern shore of Loch Inchard. One-inch map 113. Six-inch Sutherland 22 S.W.

Slice No. S. 19644. Lab. No. 552.

Large granite intrusion. Corrennie Quarry at Tillyfourie Railway Station, Aberdeenshire. One-inch map 76. Six-inch Aberdeen 63 S.E.

Slice No. S. 19626. Lab. No. 554.

Lab. No.	550	552	554
SiO_2	72·69	72·10	75·43
TiO_2	trace	trace	·32
Al_2O_3	14·46	15·14	13·06
Fe_2O_3	·72	·63	·69
FeO	not found	·05	·28
MnO	·10	·06	·11
CaO	·28	·27	·92
MgO	·03	·03	·12
K_2O	8·90	9·35	5·09
Na_2O	2·48	2·05	3·85
Li_2O	not found	not found	trace
H_2O at 105° C.	·05	·05	·06
H_2O above 105° C.	·23	·21	·20
P_2O_5	·23	·10	·07
Total	100·17	100·04	100·20

Anal. E. G. RADLEY.

Mineral in veins in Bauxitic Fireclay. Saltcoats shore, Ayrshire. 1 in. sheet 22. 6 in. Ayr. 16.

Museum No. 12138. Lab. No. 604.

	Lab. No. 604.	Kaolinite $H_4Al_2Si_2O_9$.
SiO_2	45·35	46·60
TiO_2	·16	—
Al_2O_3	39·13	39·49
Fe_2O_3	·86	—
FeO	not found	—
MnO	trace	—
CaO	·03	—
MgO	·20	—
K_2O, Na_2O	trace	—
H_2O at 105° C.	·43	—
H_2O above 105° C. ...	14·12	13·91
P_2O_5	·10	—
Total	100·38	100·00

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V.—PALÆONTOLOGICAL WORK.

England and Wales.

New ammonites and other fossils obtained by Mr. Pringle from borings in Norfolk have added materially to our knowledge of the Kimmeridge Clay and its zonal characterization. The subzone of *Saccocoma*, as indicated by the presence of the name-fossil, was recognised in the Virgatites Beds at localities near King's Lynn. The pyritized radial plates of *Saccocoma*, first found at this horizon in Kent and later in Dorset, have now been proved to have a wide distribution and to provide an important datum-line easily recognisable in borings.

The identification of certain fossils obtained from the Llanfyllin district has shown that the palæontological evidence is essential to the correct geological mapping of that area.

Some ammonites collected by Dr. Kitchin and Mr. Pringle from below the Interruptus Zone of the Gault south of Leighton Buzzard have been added to the Survey collections. They comprise species of *Leymeriella* and *Sonneratia*, which characterize the zone of *Leymeriella tardefurcata* (d'Orb.) in parts of France and Germany. The development of this zone in England had not been previously recorded, although attention had been drawn to its absence in Kent and in the Boulonnais.[1]

Much revision-work was carried out in the Museum by Mr. Allen before his retirement. He transferred to the exhibition-cases many type-fossils and other specimens formerly in the collection of the Geological Society.

The following specimens in the Museum have been figured and described:—

In the Palæontographical Society's Volume for the year 1917. (Published 1919).

A Monograph of the British Palæozoic Asterozoa.

By Dr. W. K. Spencer, M.A.

Platanaster ordovicus *Spencer*, text-figs. 114–118, 120, 121, p. 171.

The Fossil Fishes of the English Wealden and Purbeck Formations.

By Dr. A. Smith Woodward, F.R.S.

Pholidophorus ornatus *Ag.*, pl. xxi, fig. 4, pp. 103–105.

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[1] 'The Faunal Characters and Correlation of the Concealed Mesozoic Rocks in Kent,' Appendix i, in 'Summary of Progress for 1918,' *Mem. Geol. Surv.*, 1919, p. 45.

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A Monograph of the British Cambrian Trilobites.

By Mr. P. Lake, M.A.

? Eurycare sp., pl. xi, figs. 6–8, p. 94.
Peltura scarabæoides (*Wahl.*), pl. xi, figs. 9, 10, p. 97.
„ olenoides (*Salt.*), pl. xii, fig. 4, p. 100.
Beltella depressa (*Salt.*), pl. xii, figs. 6–8, 10, p. 104.
„ verisimilis (*Salt.*), pl. xiii, figs. 2, 2a, 3, p. 107.
Parabolinella simplex (*Salt.*), pl. xiii, fig. 6, p. 110.
Angelina sedgwicki *Salt.*, pl. xiv, fig. 1, p. 112.
Dikelocephalus discoidalis *Salt.*, pl. xiv, figs. 2–5, p. 115.
„ celticus *Salt.*, pl. xiv, figs. 8–10, p. 116.

In the Geological Magazine, Vol. VI, 1919.

By Mr. R. G. Carruthers.

Cryptophyllum hibernicum *R. Carr.*, pl. xi, figs. 1–4, 6, p. 436.

In the Transactions of the Royal Society of Edinburgh, Vol. LI.

The Forest of Wyre and the Titterstone Clee Hill Coal Fields.

By Dr. R. Kidston, F.R.S.

Cingularia typica *Weiss*, pl. i, figs. 2, 2a, p. 1042.
„ cantrilli *Kidst.*, pl. i, figs. 3, 3a, 4, 4a, 5, 5a, p. 1045.
Sigillaria reticulata *Lesqx.*, pl. ii, figs. 1a-c, p. 1055.
„ transversalis *Brongt.*, pl. ii, figs. 2. 3, 3a, 4, p. 1054.
„ pringlei *Kidst.*, pl. iii, figs. 1, 1a, p. 1053.
„ nudicaulis *Boulay*, pl. iii, figs. 2, 2a, p. 1050.
„ *cf.* „ pl. iii, figs. 3, 3a, p. 1051.
„ candollei *Brongt.*, pl. iv, figs. 1, 1a, 2, 2a, p. 1049.
„ boblayi *Brongt.*, pl. iv, figs. 3, 3a, p. 1048.
„ distans *Sauveur*, pl. iv, figs. 4, 4a, p. 1051.
Lepidophloios acerosus (*L. & H.*), pl. ii, fig. 5, p. 1057.
Annularia spicata (*Gutbier*), pl. ii, figs. 6, 6a, 7, 7a, p. 1039.
Carpolithes areolatus (*Boulay*), pl. v, figs. 1, 1a, p. 1062.
„ membranaceus *Göppert*, pl. v, figs. 8, 9, p. 1060.

Contributions to our knowledge of British Palæozoic Plants.

Part I, Fossil plants from the Scottish Coal Measures.

By Dr. R. Kidston, F.R.S.

Sigillaria elegans (*Sternb.*), pl. iii, figs. 8, 8a, p. 711.

In the Journal of the Cincinnati Society of Natural History, Vol. XXII, No. 2.

Notes on Richmond and Related Fossils.

By Dr. Aug. F. Foerste.

Orthis (Dinorthis) retrorsa *Salt.*, pl. ii, figs. 1a, b, c, p. 48.
„ („) inflata *Salt.*, pl. ii, fig. 1d, p. 48.
„ (Hebertella) llandiloensis *Foerste*, pl. ii, figs. 1e, f, g, h, ; pl. iii, figs. 3, 3a, 3b. p. 49.

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Scotland.

Fossils were collected chiefly from the Carboniferous Limestone areas of Ayrshire, which are now undergoing revision. Several borings were visited and portions of cores were also sent to the Office by coal-masters, with requests for information, which it was possible to supply.

Since resuming palæontological work Dr. Lee has been engaged principally in revising existing exhibits and preparing new material for exhibition in the Survey Gallery of the Royal Scottish Museum.

VI.—PHOTOGRAPHIC WORK.

No photographs were taken in England and Wales owing to the absence of the photographer on military duty.

In Scotland 175 photographs were taken in illustration for the geology of the Argyll, Ayr, Forfar, Aberdeen and Banff districts.

VII.—MUSEUM OF PRACTICAL GEOLOGY.

Although nominally closed during the greater part of the war, the Museum has been open to all who had definite enquiries to make. It was reopened to the public on April 1st, 1919, but the open evenings have been changed from Saturdays and Mondays to Saturdays and Thursdays. The mineral, fossil and rock-galleries are now accessible, but it has not been possible to bring up the ground-floor exhibits to their normal condition.

Exhibits of refractories, of rocks yielding oil and of natural oils have been prepared, and a series illustrative of chrysotile asbestos from South Africa and Canada. Examples of iron-ores, collected during the previous year, are being incorporated in a revised exhibit of British Iron-Ores.

A selection of stones suitable for war memorials was lent to the War Memorial Exhibition held at the Victoria and Albert Museum, and later at the Royal Academy. Many enquiries have been received on the subject of stones for memorials.

List of Donations during the year 1919.

Andrews, C. T., Esq.—Group of quartz-crystals from Congonhas de Campos, Minas Geraes, Brazil.

Ashcroft, F. N., Esq., M.A., F.C.S., F.G.S.—A series of minerals from Derbyshire and Cumberland. A series of specimens of zeolites.

Ashcroft, Miss M. E. M.—Dark-purple fluor containing a crinoid.

Dick, Allan B., Esq.—Four specimens of slags, silica from Cornwall.

Fitzmaurice, C. E. A., Esq.—Antimony and silver-lead ores from the Trevinnick Mine, Cornwall.

Gilbert, C. J., Esq., F.G.S.—Sun-cracks on sand-rock from the High-level Gravels at Little Heath, Berkhamsted.

Godden, R. A., Esq.—Island Phosphate from Curaçoa.

Green and Sons, Ltd., Messrs. J. G.—Sandstone from the Denwick Quarries, Alnwick.

Gregory, Messrs. J. R.—Phosphoro-calcite.

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HORSHAM URBAN DISTRICT COUNCIL.—Samples of the Strata from the boring at the Horsham Waterworks, 1903–4.

JONES, F. T., ESQ.—A series of minerals from Alderley, Cheshire.

KENDALL, PROF. P. F., M.Sc., F.G.S.—Sandstone intrusion in coal, 'rock-rolls'; contorted sandstone from a true 'wash-out' in the coal; sandstone 'drop' from the roof into the coal-seam.

KENNY, W. H., ESQ.—African Minerals.

LECKHAMPTON QUARRIES CO., LTD.—Samples of limestone, 'Cotswold Dale' Stone.

MARSHALL, F., ESQ.—Quartz coated with nail-head pyrites, Cornwall.

PRESTEA BLOCK A., LTD.—Gold-bearing quartz from the Gold Coast.

RENWICK, R., ESQ.—(*See* Horsham Urban District Council.)

ROGERS, DR. A. W.—A collection of Asbestos minerals from South Africa.

RUSSELL, ARTHUR, ESQ.—Copper-ores from Alderley Edge. Niccolite from Kirkcudbrightshire.

RUSSELL, F., ESQ., F.G.S.—A cast of a large *Bellerophon* from the dolomitic Carboniferous Limestone of Breedon Cloud.

RYLAND, F. J., ESQ.—Barytes from the Barlocco Mine, Auchencairn, Dalbeattie, and from the Potts Ghyll Mines, Cumberland.

SANDISON, REV. R. C.—Three specimens from the Chromite Quarries, Balta Sound, Unst, Shetland.

SKINNINGROVE IRON CO., LTD.—Artificial apatite.

TAYLOR, CAPTAIN W.—Scheelite and wolfram with mispickel, East Pool Mine, Cornwall.

TRUEMAN, DR. A. E., F.G.S.—Specimen of dark micaceous shale with lamellibranchs, from the *Oistoceras* sub-zone (top of Lower Lias) of Bracebridge, south of Lincoln.

VARCOE, R. W., ESQ.—China-stone with tourmaline, Cornwall.

WALEY, F. R., ESQ.—Several small specimens of ancient marbles; specimens of sal ammoniac, ruby, emerald, oil-shales, etc.

WALFORD, E. A., ESQ., F.G.S.—A *Rhynchonella* from the Great Oolite of Aynho.

WORTH, R. H., ESQ., F.G.S.—Montmorillonite from near Meldon, Devon.

ZAFFERE, P., ESQ.—Gold Ore, Alpes Mine, Southern Rhodesia.

VIII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MAPS.

Six-inch reference Maps.

The following 35 standard copies of Six-inch quarter-sheets have been made from the field copies, and are available for reference:—

Cumberland, 48 N.W., N.E., S.W., S.E.

Kent, 2 S.W., S.E.; 8 N.W., N.E., S.E.; 9 S.W.

London, 1 S.E.; 10 S.W.; 11 S.W., S.E.

Pembrokeshire, 38 N.E., S.E.; 39 N.W., N.E., S.W., S.E.; 40 N.W., N.E. S.W., S.E.; 41 S.W., S.E.; 42 N.W., N.E., S.W., S.E.; 43 N.W., N.E. S.W.; 44 N.W., N.E.

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II.—Memoirs:

Published Memoirs.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1918, 70 pp.; 3 text figures. Price 2*s.* 6*d.* net.

Special Reports on the Mineral Resources of Great Britain:—

Vol. VIII.—Iron Ores: Hæmatites of West Cumberland, Lancashire, and the Lake District. By Bernard Smith, M.A., 182 pp., 4 plates; 29 text-figures. Price 9*s.* net.

Vol. IX.—Iron Ores (*contd.*): Sundry Unbedded Ores of Durham, East Cumberland, North Wales, Derbyshire, The Isle of Man, Bristol District and Somerset, Devon and Cornwall. By T. C. Cantrill, B.Sc., R. L. Sherlock, D.Sc., and Henry Dewey, 87 pp.; 7 text figures. Price 3*s.* 6*d.* net.

Vol. X.—Iron Ores (*contd.*): The Hæmatites of the Forest of Dean and South Wales. By T. Franklin Sibly, D.Sc., 93 pp.; 14 text-figures. Price 4*s.* net.

The Geology of the Country around Lichfield, including the Northern Parts of the South Staffordshire and Warwickshire Coalfields. (Explanation of Sheet 154.) By G. Barrow, W. Gibson, D.Sc., T. C. Cantrill, B.Sc., E. E. L. Dixon, B.Sc., and C. H. Cunnington, B.Sc., with contributions by J. B. Hill, R.N., T. Eastwood, A.R.C.Sc., and J. Pringle, 302 pp.; 1 plate; 6 text figures. Price 9*s.* net.

SCOTLAND.

I.—Maps.

Six-inch Reference Maps.

The following copies of six-inch maps have been completed and deposited in the office for reference:—

Inverness, 20; 155 N.W., N.E., S.W.
Kincardine, 1 N.E., S.W., S.E.; 2 S.W., S.E.; 10, 11, 15, 16; 18 N.E., S.E.; 19, 20; 22 N.E., S.E.; 23, 24; 26 N.W., N.E., S.E.
Nairn, 6.
Perth, 16 S.W.; 17.
Renfrew, 4 S.W.

The following clean copies, deposited provisionally in 1915–16 owing to the absence of officers on active service, have been checked, revised and deposited in the office for reference:—

Argyll, 10, 11, 19; 30 N.W., S.W., S.E.; 31, 32; 43 N.W., N.E., S.E.; 45, 46, 57, 59, 60.

Inverness, 150 N.E., S.W., S.E.; 151, 152, 159 S.E.; 160, 161, 162, 165 N.E.; 166, 167 N.W., N.E.; 168 N.W., N.E., S.E.

The revision work of the Silurian areas of the Southern Uplands of Scotland has been added to the following six-inch clean copies (Old Series Maps), and these are now completed and deposited in the office for reference:—

Kirkcudbright, 28 N.W., N.E., S.E.; 29.
Wigtown, 5, 6, 7, 8 N.W., S.W., S.E.; 9, 10, 11, 12, 13, 14 S.W.; 15, 16, 17, 18, 19, 20, 21 N.W., N.E., S.E.; 22, 23 N.W., N.E., S.E.; 24, 25, 26, 27, 28 N.E.; 29, 30, 31 N.W., N.E., S.E.; 32 N.W., S.W.; 33 N.W., N.E., S.E.; 34; 35 N.W., S.W.; 36 N.W., S.W., 36a N.W.; 37 N.W., N.E.

II.—Memoirs.

Published Memoirs.

Summary of Progress for 1918. *See* above.

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APPENDIX I.

On a boring for Coal at Brayton Domain Colliery, Cumberland.

By Bernard Smith, M.A.

Brayton Domain Colliery is situated about 2 miles N.E. of Aspatria. The Coal Measures are reached by sinking through St. Bees Sandstone, which forms the northern limit of the exposed coalfield. The accessibility of the concealed coalfield was discussed in the Final Report of the Royal Commission on Coal Supplies, Part IX, p. 17 (1905), and it was concluded that a fault which was supposed to introduce the St. Bees Sandstone along the whole of this margin of the coalfield, must be small, if it exists, at Brayton and east of it. The explorations described in the following pages provide no evidence of such a fault. On the contrary they show that the St. Bees Sandstone is of trifling thickness near the margin, but increases rapidly northwards. A more serious obstacle to reaching the coal, however, lies in the increasing thickness of barren red measures in that direction.

At No. 4 Pit, Brayton, the Yard Band Coal of the Middle Coal Measures is worked at a depth of about 552 ft., on the south-west side of a fault with a downthrow of 30 fms. south-west (Fig. 2). To the east of this fault, where the coal has been worked, the Heathfield borehole proved the top of the Yard Band Coal, 4 ft. 6 in. in thickness, at a depth of 561 ft. 8 in. from the surface; the grey productive measures being overlain by 22 ft. of boulder clay on 46 ft. 5 in. of St. Bees Sandstone, on approximately 292 ft. 5 in. of unproductive (supposed Upper) Coal Measures. A little farther east a large fault with north-eastward downthrow has been touched in the workings at 80 fms. depth.

To prove the ground beyond this fault, borehole No. 1 was put down. This passed through 100 ft. of boulder clay, 456 ft. 4 in. of St. Bees Sandstone, and 706 ft. of unproductive measures, a total of 1,262 ft. 4 in., when the boring was abandoned owing to difficulties. Borehole No. 2 was then commenced slightly north of east of No. 1. Passing through much the same sequence it entered grey productive measures at 1,384 ft. 3 in. and passed through the top of the Yard Band Coal (3 ft. 9 in.) at 1,855 ft. 11 in., the bottom of the boring being at 1,870 ft.

Farther evidence as to the lie of the Yard Band Coal in this area being required, another boring, No. 3, was decided upon. By March, 1918, this boring had reached a depth of 2,050 ft. and was still in unproductive measures, when the Geological Survey was invited to examine the cores with a view to helping in a decision whether these measures should be assigned to the Upper Coal Measures or to some other formations. We are indebted to Mr. G. H. Askew, and to Mr. Thomas Eadie, the Colliery Manager, for valuable records of other borings and workings in the vicinity.

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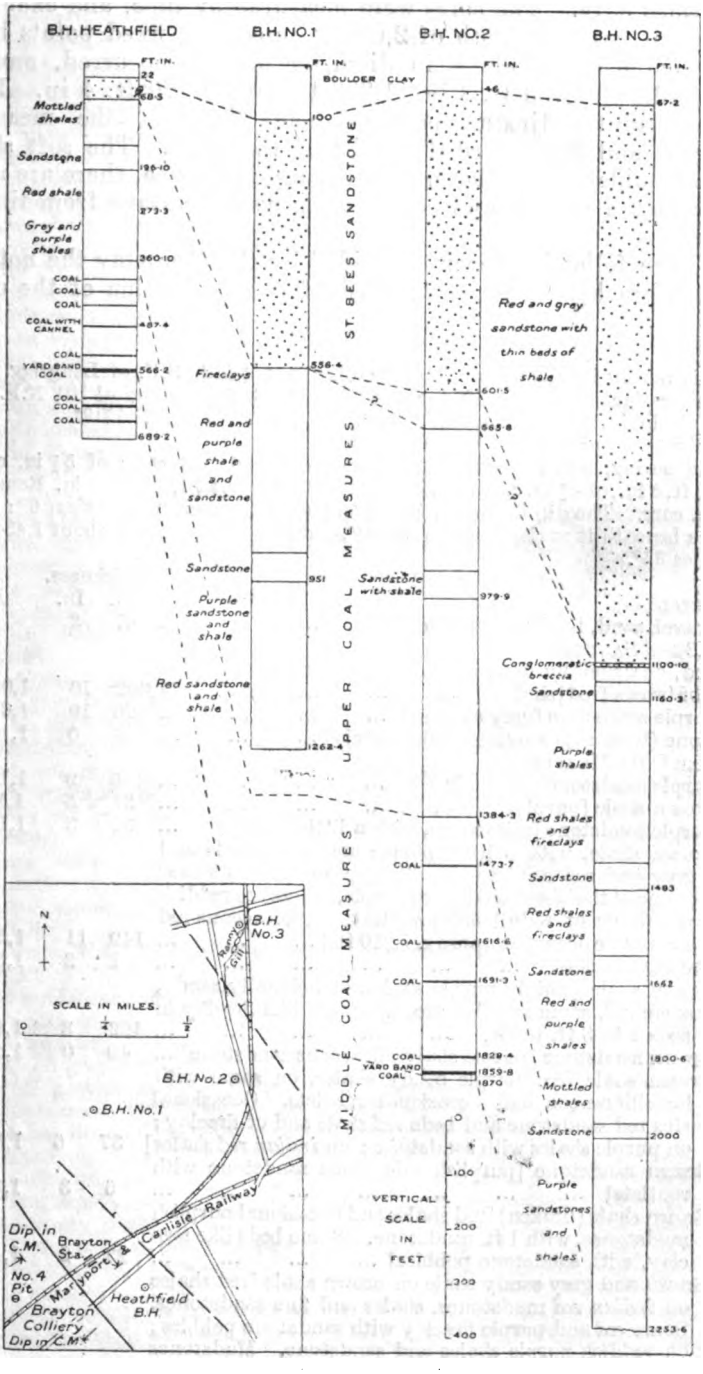
FIG. 2.—BORINGS FOR COAL AT THE BRAYTON COLLIERY, CUMBERLAND.



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Only the cores below 1,000 ft. had been kept in order, the remainder having been scattered. As no depths were marked on them, it was possible, in many cases, to give approximate positions only. The cores were measured by tape, and examined in detail, from a depth of 2,081 ft. upwards, fixed points being obtained where changes in diameter of core occurred, namely, at depths of 1,789 ft. 3 in., 1,296 ft., and 1,170 ft. 4 in. From these points adjustments were made between the measured lengths and the recorded depths of the cores. The soft shales gave trouble to the borers by caving in; hence there are many gaps in the record, and cementation was necessary from time to time.

To the following record provided by the Company the notes in square brackets have been added after examination of the cores.

Borehole No. 3 (*Fig.* 2).

This boring is situated at Ranny Gill, about ¼ mile S.E. of Langrigg. New Series one-inch Ordnance Map, Sheet 23; Old Series Geological 101 N.E. Six-inch Geological, Cumb. 28 S.W. Lat. 54° 47′5″. Long. 3° 17′8″.

Height of surface above O.D., 90 ft.

The boring, by diamond-drill, commenced 1916. Bottom of 5¼ in. core at 1,170 ft. 4 in., of 4¼ in. core at 1,296 ft., of 3¼ in. core at 1,789 ft. 3 in. Remainder 2¾ in. core. The dip in the St. Bees Sandstone is generally less than 6°; in the shales beneath it varies from 15° to 30°, and in a sandstone at about 1,434 ft., it reaches 35°.

	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
GLACIAL:—				
Gravel, sand, boulders and pinnel	67	2	67	2
ST. BEES SANDSTONE:—				
Red, occasionally grey, sandstone, with numerous beds of brown [red] shale	1,002	10	1,070	0
Purple sandstone [grey at base]	26	10	1,096	10
Stone (bastard) [conglomeratic breccia]	4	0	1,100	10
UPPER COAL MEASURES:—				
Purple sandstone and shale	5	9	1,106	7
Brown shale [purple]	21	5	1,128	0
Purple sandstone [micaceous, with a little shale] ...	32	3	1,160	3
Brown shale, with a little purple and grey shale and grey and red sandstone, with gypsum veins at base [some of the above shales are purple, others are reddish purple or of a dull *brick-red* tint. A micaceous red sandstone occurs at approx. 1,210 ft.]	149	11	1,310	2
Grey sandstone	1	2	1,311	4
Brown shale [mainly purple shales, occasionally sandy, some *red*, some mottled green. Some like fireclay in beds 2 to 3 ft. thick]	122	8	1,434	0
Brown sandstone [purple shaly micaceous sandstone] ...	49	0	1,483	0
Brown shale [red purple sandy shales, on same with lamellibranchs and occasional rootlets. Occasional ribs red sandstone and beds *red* shale and of fireclay; on purple shales with sandstone; on *indian red* shales]	37	6	1,520	6
Brown sandstone [purplish micaceous sandstone with rootlets]	6	3	1,526	9
Brown shale (broken) [red shales and occasional purplish mudstones, with 1 ft. sandstone. Some beds like fireclay, with sandstone pebbles]	27	2	1,553	11
Brown and grey sandy shale on brown shale [red shales on *indian red* mudstones, shales and fine sandstones. Some *red* and purple fireclay with sandstone pebbles; on reddish-purple shales and sandstone. Mudstones and shales occasionally *bright brick-red* and fine-grained]	35	8	1,589	7

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	Thickness. Ft.	In.	Depth. Ft.	In.
Brown sandstone [reddish purple sandstone on purple micaceous sandstone with red joints]	7	6	1,597	1
Brown shale [purple shales on reddish purple fireclay (3 ft.) on variegated purple shales with pebbles and fragments of red shale]	10	1	1,607	2
Brown sandstone tinged with blue [purple]	5	7	1,612	9
Reddish-grey sandstone [grey-purple and micaceous] ...	49	3	1,662	0
Brown and grey shale (3 ft. 10 in.) on grey-blue and brown shale [purple shales, occasionally sandy, on grey or mauve shales with fragments hæmatite and red shale. Occasional beds like fireclay, with rootlets]	24	1	1,686	1
Brown sandy sandstone [purple, brown and *salmon* shales, occasionally purple; dip about 30°]	76	5	1,762	6
Brown shale (a little sandstone at 1793–4 ft.) [purple and reddish-purple micaceous shales and mudstones; dip 20°]	38	0	1,800	6
Grey sandstone [purple]	0	8	1,801	2
Purple shale [red mudstone]	2	5	1,803	7
Brown shale [red and purple mudstones, mottled green near base]	24	9	1,828	4
Brown shale [purple and *red* mudstones, some mottled]...	5	4	1,833	8
Brown sandy shale [purple micaceous shaly sandstone]	9	8	1,843	4
Brown shale [purple shales, some sandy and micaceous and slickensided]	12	3	1,855	7
Grey flint (very hard) [grey quartzitic sandstone] ...	0	7	1,856	2
Brown shale [purple mudstones (3 ft.) on *indian-red* mudstones and shales, occasionally purplish amd micaceous]	32	3	1,888	5
Brown shale tinged with blue [purplish, sandy and micaceous, mottled green]	9	2	1,897	7
Brown shale [reddish purple, sandy and micaceous, with gypsum]	5	0	1,902	7
Brown shale (broken) [purplish and sandy; slickensided]	15	8	1,918	3
Brown shale [purple and sandy, gypsum in joints; dip 35°]	3	10	1,922	1
Dark grey sandstone [purple-red siliceous sandstone] ...	7	4	1,929	5
Brown shale [mottled purple mudstones, and purple-red sandstone with gypsum, on red-purple mottled mudstones, on blue-purple ditto]	23	1	1,952	6
Hard brown stone [siliceous sandstone]	0	3	1,952	9
Brown and grey shale [purplish-red mudstones, mottled green]	18	0	1,970	9
Brown shale [sandstone, 30 ft., some speckled; on marls and shales]	60	7	2,031	4
Brown shale with a little grey shale [reddish-purple shales]	8	5	2,039	9
Brown sandstone mixed with grey [mottled mudstone, etc.]	25	6	2,065	3
Red sandstone [purplish]	1	1	2,066	4
Brown shale [„]	1	0	2,067	4
Red sandstone [„]	2	9	2,070	1
Red and grey sandstone full of mica [purplish-red shale with greyish sandstone bands, very micaceous and ripple-marked. Some purplish sandstone; dip 20°]	8	3	2,078	4
Red sandstone mixed with grey [medium grained purple, micaceous, felspathic false-bedded sandstone, layers nearly horizontal]	15	2	2,093	6
Total depth bored April 14, 1919, *was* 2,086 *ft.*				
Blue sandy shale	1	3	2,094	9
Red sandstone mixed with grey	2	9	2,097	6
Brown shale and grey sandstone	63	8	2,161	2
Grey shale	0	4	2,161	6
Grey sandstone and brown shale	1	9	2,163	3
Brown shale and sandstone	16	4	2,179	7
Brown and grey shale with mica	3	11	2,183	6
Brown sandstone with mica	3	0	2,186	6

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	Thickness. Ft.	In.	Depth. Ft.	In.
MIDDLE COAL MEASURES ? :—				
Brown and blue shale	10	9	2,197	3
Grey sandstone	0	4	2,197	7
Brown and grey sandy shale [red and greyish-purple micaceous sandstone and shale; dip of shales, 15°] ...	20	5	2,218	0
Blue brown shale	10	3	2,228	3
Grey brown shale	3	7	2,231	10
Blue and grey shale	3	0	2,234	10
Brown and blue shale	1	0	2,235	10
[Not reported]	1	8	2,237	6

Total depth bored, measured by rods, Feb. 11, 1920, *was* 2,253 ft. 6 in.

Boring was stopped at this point and the hole cemented up, as a great quantity of dirt was dropping to the bottom.

In the above record the base of the St. Bees Sandstone has been placed at the bottom of a 4 ft. bed of conglomeratic breccia; the immediately overlying purple and grey sandstones being, apart from colour, similar in character to the red and grey sandstones of higher horizons. There being a difference in the level of this base of about 500 ft. between this boring and B.H. No. 2, it is clear that a post-Triassic fault of considerable throw intervenes.

The conglomerate consists mainly of rounded and subangular fragments set in a grit with a dolomitic matrix. The larger fragments include pebbles of marl (some ironstained), dolomite, dolomitic marl and silty marl. Some of the marly fragments appear to contain organic structures. The grit includes round and angular grains of clastic quartz, grains of silty marl, occasional felspars with albite twinning, crushed quartzite and mica.

With regard to the beds below the breccia, few of the shales are brown; the majority are of purple hue, occasionally bluish-purple, but more usually reddish-purple. Red mudstones and shales occur at intervals down to nearly 1,900 ft. Some of them are chocolate-red, when dry; others bright brick-red, when wet. Their occurrence suggests that the colouring of part at least of the series is original, and not due to secondary staining. Purplish mudstones or clays, traversed by rootlets and resembling fireclays, both in appearance and mode of weathering, occur at several horizons, but are rarely more than 3 ft. in thickness. They contain pebbles of sandstone and marl of irregular shapes.

At lower levels the mottled shales or mudstones are distinctive. They frequently present an appearance of being brecciated, and contain small pebbles of marl, sandstone, and occasionally hæmatite. A specimen from approximately 2,048 ft. was sliced, and proved to be a patchy mudstone, of which the paler portions are sericitic paste rock with some chlorite, whilst the darker portions are ironstained. The brecciated appearance in a hand-specimen is due chiefly to the unequal segregation of iron-oxide. There were a few quartz-grains and a little carbonate material.

The sandy beds are of a purplish tint as a rule, although some are reddish, whilst the more siliceous members vary from greyish-

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purple to grey. The speckled purplish-red sandstone at about 2,020 ft. is a distinctive type, which might be recognised in neighbouring boreholes. The specks are possibly due to iron; they do not appear to be manganese.

The occurrence of bluish shales in the lower 50 ft. of the record suggests that the productive Middle Measures may possibly have been entered.

In conclusion, the lithological types are similar to those found in neighbouring boreholes, and to those attributed to the Upper Coal Measures in the Midland Coalfields. They also compare closely with the Red Sandstone Group or Upper Coal Measures of the Canonbie Coalfield[1], as shown in the records of the Roanburn and Forge borings.

The lamellibranchs occurring between 1,483 and 1,520 ft. 6 in. are poorly preserved, and have been identified by Mr. J. Pringle as *Anthracomya?* They are closely similar to certain ill-preserved shells referred to *Anthracomya* found in the Keele Beds at Thurgarton (1,037 ft.) by Dr. W. Gibson[2], and at Farnsfield (855 ft.) by Prof. H. H. Swinnerton[3]. They also occur commonly in the Newcastle Beds.

There seems to be little doubt, therefore, that these beds are in the main of Upper Coal Measure Age, and form part of the Whitehaven Sandstone Series, as argued by Mr. J. D. Kendall[4].

The following points arise for discussion:—

1. Is the Whitehaven Sandstone Series unconformable to the Productive Measures?
2. What is the significance of the northward thickening of that series beneath the New Red Sandstone?

1. The colours of these beds appear to be, in the main, original. Their base, as pointed out by Kendall, is difficult to detect, because they are of similar lithological types to the Middle Coal Measures, and subject to rapid variations. The colour is no guide, for the purplish or reddish tint may or may not extend to the base at all points, and may in some cases occur even in the higher parts of the productive measures, as at Buckley in Flintshire, and to a small extent also in the Warwickshire Coalfield; or even at lower horizons, as in the case of a group of 189 ft. of red sandstones and shales that occurs nearly 1,000 ft. down in the grey measures at Wallingwells (Firbeck Colliery) on the borders of Yorkshire and Nottinghamshire, and generally between Rotherham and Retford. The 'Rotherham Red Rock,' again, with which the Whitehaven Sandstone has been compared, is now considered to include one or more rocks[5], not necessarily at the same horizon, in the Middle Coal Measures.

[1] *Trans. Royal Soc., Edinburgh*, vol. xl, pt. iv (No. 32), 1903, pp. 858–865, and 'Summary of Progress' (*Mem. Geol. Surv.*) for 1902, 1903, pp. 214–6.

[2] Unpublished.

[3] Unpublished, but specimens preserved in the Palæontological Department of the Geological Survey.

[4] 'The Whitehaven Sandstone Series,' *Trans. Fed. Inst. Min. Eng.*, vol. x, 1895–96, pp. 202–224.

[5] Prof. P. F. Kendall, *Final Rep. Roy. Com. on Coal Supplies*, part ix, Appendix iii, 1905, p. 22.

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J. D. Kendall maintains that there is a considerable unconformity between the two groups. His conclusion is based partly upon lithology and colour, but largely upon the varying thickness between the Yard Band Coal and the supposed base of the Whitehaven Sandstone Series at different points, and also on the supposed persistence of two coal-seams near the base of the Whitehaven Sandstone Series in the northern area.

The fact remains, however, that the base of the series cannot at present be fixed either by fossil evidence or by lithological character, and the absence of certain coals, near the top of the Middle Coal Measures, is at best negative evidence, and may be due to impersistence.

Newell Arber[1] claimed that the lower 200 ft. at least of the Whitehaven Sandstone Series was of Middle Coal Measure age, and that the unconformity, if present, between the Sandstone Series and the Productive Measures does not mark any considerable interval in geological time.

The Whitehaven Sandstone Series proved in the Brayton No. 3 borehole consists largely of shales, the proportion of shale to sandstone being roughly as 75:25, figures that agree with Kendall's estimate of the proportions in the series in this area.

2. At Frizington Hall, near Whitehaven, 531 ft. of Whitehaven Sandstone has been proved by boring[2]. The top had been denuded, but Arber estimated the full original thickness to have been at least 600 ft. At Brayton No. 3 boring a vertical depth of over 1,000 ft. of these rocks has already been penetrated, representing a true thickness of about 900 ft.

The Brayton boreholes show an increase in thickness (measured vertically) in a northerly direction of about 800 ft. in a little over one mile. Dips measured on the cores of No. 3 give an average difference of about 15° between the dip of the St. Bees Sandstone and that of the underlying strata. If we assume that these Carboniferous Rocks were dipping northwards towards the centre of the Carlisle Basin before the deposition of the New Red Sandstone and the occurrence of later faulting, a dip of this amount over a horizontal distance of a mile would give an increased (vertical) thickness of about 1,420 ft. Hence the difference in dip provides a sufficient explanation of the increase in thickness (without considering possible movements at different dates along fault-lines), even if we take it that the direction of dip of the beds was rather north-north-westward than true north.

The conclusion seems to follow that should the above rate of thickening continue northward, together with an increasing depth of Triassic cover, the productive Middle Coal Measures will be carried down rapidly to depths at which they cannot be reached and worked with profit.

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[1] 'The Fossil Flora of the Cumberland Coalfield, and the Palæobotanical Evidence with regard to the Age of the Beds,' *Quart. Journ. Geol. Soc.*, vol. lix, 1903, pp. 1–22.

[2] 'The Whitehaven Sandstone Series,' *Trans. Fed. Inst. Min. Eng.*, vol. x, 1895–6, pp. 215–216.

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APPENDIX II.

On the North-Western corner of the Lothian Oil-shale Field.

By G. W. Lee, D.Sc.

The north-western corner of the Scottish Oil-shale Field, consisting of an area of some two or three square miles around Blackness village (Six-inch Sheet, Linlithgow, 2 S.W.), has long been of interest to all connected with the oil-shale industry. Little was known of the district, as testified by the fact that the existing geological maps do not carry the lines of crop of the workable shale seams much further west than Philpstoun, but the simple structure of the ground, the geologically high position of the strata, and the continuity of the district with the valuable Philpstoun shale-field, were regarded as offering distinct possibilities of untapped resources[1]. Recent boring operations were therefore closely followed by the Geological Survey. The results were unsatisfactory from the mining point of view, but of considerable geological interest, and we have to express our indebtedness to Mr. J. Kidd, M.P., for his permission to make use of the information obtained.

No. 1 bore was put down on the west bank of the Black Burn, $\frac{1}{8}$ mile S.E. of Blackness, and No. 2 bore in a little quarry on the shore, 500 yards west of Blackness. As there is on the whole an ascending sequence from east to west, the second bore starts in a newer stratum than the first, and as it was carried down to the same horizon it offers the fuller sequence.

The following is condensed from the borer's log:—

	Thickness. Fm.	ft.	in.	Depth. Fm.	ft.	in.
Rubbish, blaes[2] and balls	–	–	–	3	3	0
Dark-grey limestone	0	1	6	3	4	6
Strata (mostly blaes)	4	–	–	6	1	9
Oil-shale	0	0	4	6	2	1
Sandstone	–	–	–	6	–	–
Limestone, brown earthy	0	0	3	6	3	9
Strata (mostly fakes and sandstone)	–	–	–	11	4	9
Blaes	–	–	–	16	4	6
Sandstone, fakes, blaes and ironstone	–	–	–	37	0	6
Black blaes	3	2	7	40	3	1
Dark-grey shale with fossils	0	5	0	41	2	1
Strata, mostly blaes with four beds of sandstone and a teschenite-sill 160 ft. thick	–	–	–	97	0	0
Shaly blaes and grey blaes	1	3	6	98	3	6
Dark-grey blaes with limy ribs and balls	2	2	2	100	5	8

[1] 'The Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., p. 65.

[2] For explanation of terms used by Scottish borers, *see* p. 34, footnote.

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	Thickness. Fm.	ft.	in.	Depth. Fm.	ft.	in.
Strata (mostly blaes and fakes)	–	–	–	109	3	8
Ash	1	3	1	111	0	9
Strata	–	–	–	112	3	10
Ash	0	4	2	113	2	0
Blaes	–	–	–	120	5	1
Limestone and ironstone	0	0	6	120	5	7
Shaly blaes	0	1	4	121	0	11
Fakes	0	1	4	121	2	3
Coal	0	1	2	121	3	5
Marl	7	3	11	129	1	4
Fakes and fireclay	–	–	–	130	2	8
Coal plies	0	0	1	130	2	9
Fireclay, fakes, blaes	–	–	–	139	1	0
Coal	0	0	3	139	1	3
Fakes	–	–	–	141	1	0
Sandstone	5	5	6	147	0	6
Fakes and sandstone and faky blaes	–	–	–	154	3	6
Blaes	0	3	6	155	1	0
Limestone	3	3	11	158	4	11
Greenish marl	0	0	5	158	5	4
Strata, mostly burnt blaes	1	2	10	160	2	2
Coaly blaes, burnt	0	1	9	160	3	11
White whin and burnt blaes	–	–	–	162	2	5
Limestone	1	2	3	163	4	8
Fakes and sandstone	4	5	6	168	4	2
Sandstone	4	3	0	173	1	2
Strata, mostly fakes	–	–	–	180	5	2
Blaes with a layer of large *Estheria*	5	4	0	186	3	2
Black limestone	0	0	3	187	0	2
Sandstone, fakes and clay	2	0	0	189	0	2
Limestone	5	4	1	194	4	3
(Bore stopped in limestone.)						

The limestone at the depth of 3 fathoms 4 ft. 6 in. is hard, grey, crinoidal and contains remains of *Productus*, *Lingula*, and other fossils. Its characters agree with those of the Riccarton Limestone, which lies not far below the Cobbinshaw position[1]. It is to be noted that in the West Calder district a thin crinoidal limestone has been met with 25 fms. below the Cobbinshaw ('Hurlet') Limestone and Coal.

The black blaes at 40 fms., which have been burnt by the sill lower down, are of a sufficiently fine texture to be regarded as having possibly once been of the nature of oil-shale. The blaes which underlie them are of marine origin and contain remains of goniatites. It is a significant fact that goniatites have been found below the Fraser Shale position in the West Calder district, and that the distance between that shale and the crinoidal limestone is there almost the same as in the Blackness boring, viz.—about 40 fms. The inference is that this burnt blaes represents the Fraser Shale. The next stratum of interest is the "shaly"

[1] 'The Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., 1912, p. 65.

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blaes, or poor oil-shale at 98 fms. A marine fossiliferous bed underlies it, in which goniatites and the lamellibranch *Posidonomya becheri* are conspicuous. These fossils, again, are known from under the Raeburn Shale. That this 'shale' is the Raeburn is all the more probable when its position is considered relatively to that of the bed taken to be in the Fraser Shale position, and to that of the Two-Foot Coal—the next recognisable index: in both cases after deduction of the sill the distances agree well with the distances between these seams in the West Calder district. The position of the Two Foot Coal is clearly represented by the impure coal at 121 fms., and the Houston Marl is developed with the usual characters. The above remarks show that in the Blackness district the strata between the base of the Carboniferous Limestone and the base of the Houston Marl possess the development and aspect of the equivalent strata in the typical oil-shale districts, the only difference being in the quality of the shales, which here have no economic value. On the other hand, from the Houston Marl downwards to the Burdiehouse Limestone there is a sudden and remarkable departure from the normal.

It ought to be stated that the cores of the borings were carefully examined by a skilled borer, and at frequent intervals by the writer for the purposes of this report, with special reference to any possibility of faulting. No trace of faulting was detected anywhere below the Houston Marl. The Houston Coal and Grey Shale, poorly represented in No. 1 Bore, have almost disappeared in No. 2 Bore. The Fells Shale is totally absent, arenaceous sediments taking its place. The Broxburn Marls have disappeared except for a layer 5 in. thick of greenish colour and of the usual soapy texture; and, on the other hand, there is an exaggerated development of the "cement" bands usually found in the Marls: here they form thick limestones which occupy the larger part of the series. The Broxburn Shale is recognisable in No. 1 Bore and is 10 ft. thick. The oil-content is only 9 gallons per ton, but the oil is of high quality. The sulphate of ammonia amounts to 40 lbs. per ton. In No. 2 Bore the position is occupied by blaes, burnt by a small sill. In the first bore the Broxburn position is 35 fms. below the base of the Houston Marls, and only 30 fms. in the second bore.

The strata between the Broxburn position and the Burdiehouse Limestone show extreme attenuation, the distance being 49 fms. in No. 1 Bore, and only 29 fms. in No. 2 Bore, against over 100 fms. in the Philpstoun field. The solid sandstone some 10 fms. below the Broxburn position may be taken to be the Binney Sandstone, but there is no trace of the Dunnet Shale, nor is there room for the thick set of strata which normally would come below.

In No. 1 Bore a poor oil-shale 14 ft. thick rests on the top bed of the Burdiehouse Limestone, and would thus represent the Camps Shale. It underlies a light-brown entomostracan limestone about 12 ft. thick, which may possibly take the place of cement-ribs met with about that position in the Philpstoun field. In No. 2 Bore the poor oil-shale is replaced by black blaes, and the overlying limestone is absent.

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The Burdiehouse Limestone is of the usual type and of considerable thickness. In No. 1 Bore 3 fms. of blaes separate a top bed 42 ft. 6 in. thick from a lower bed in which the boring stopped.

To sum up, these two borings indicate, firstly, that the Blackness district does not contain reserves of oil-shale; secondly, that the sequence above the Houston Coal position is fully developed; and, thirdly, that the sequence between the Houston Coal and the Burdiehouse Limestone shows intense attenuation.

These points are brought out in the sections forming Fig. 3, two of which, namely, that of West Calder and that of Bridgend, are borrowed from the Geological Survey Memoir.

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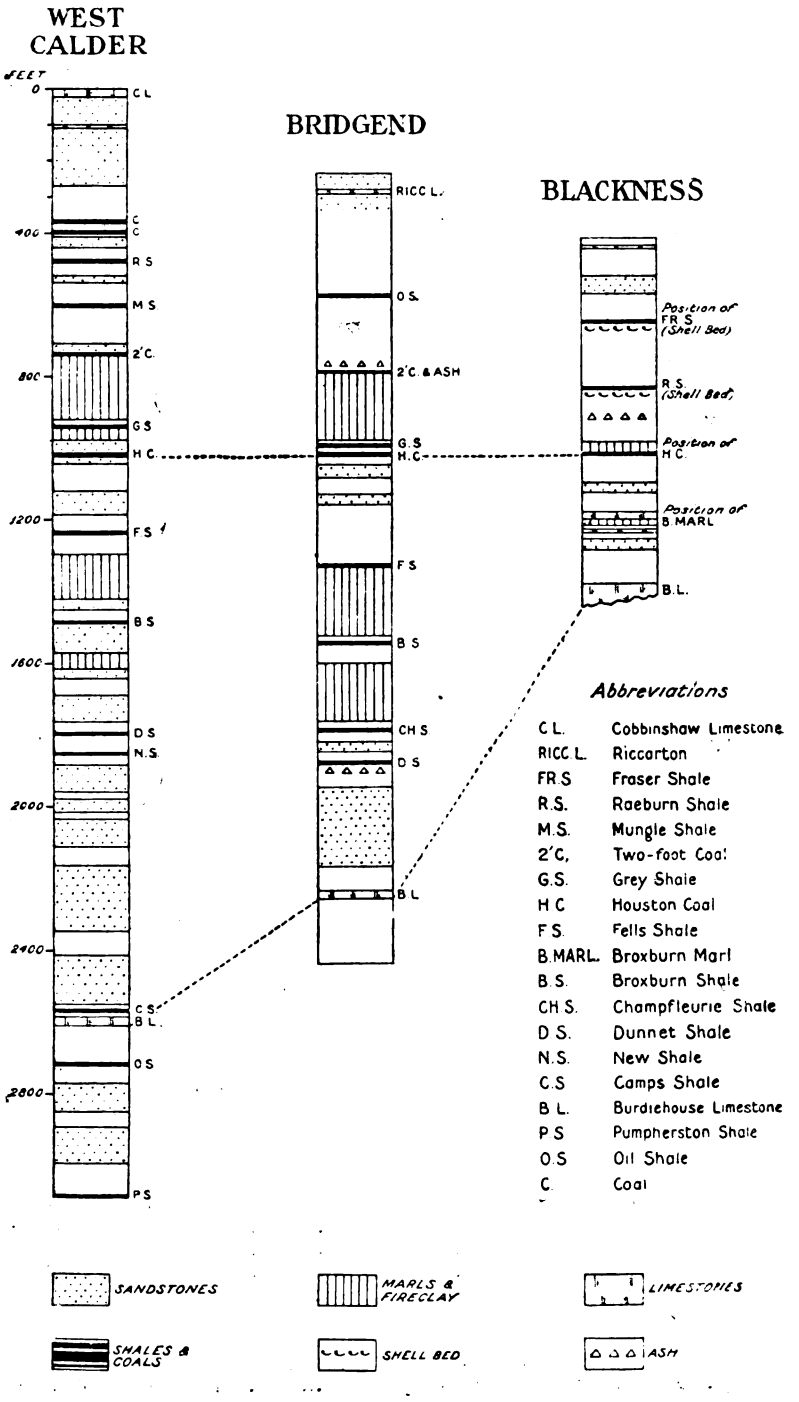
FIG. 3.—COMPARATIVE VERTICAL SECTIONS, SHOWING ATTENUATION OF THICKNESSES IN THE NORTH-WESTERN CORNER OF THE LOTHIAN OIL-SHALE FIELD.



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APPENDIX III.

Coventry Colliery.

By T. Eastwood.

The colliery is situated near Newland House Farm, Keresley, in the New Series One-inch Map 169, and the Six-inch, Warwick, 16 S.E.

There seems to be a widespread notion in the Midlands that workable coals terminate southwards on the latitude of the southern end of the South Staffordshire Coalfield. Recent explorations in Warwickshire prove that, at any rate near the prescribed boundary, workable seams of good quality are present. In the 'Summary of Progress for 1914' (*Mem. Geol. Surv.*) an account is given of two borings put down by the Warwickshire Coal Co., at Keresley and Whitmore Park. Since then the colliery shafts at Keresley have been completed, and, in view of possible future explorations to the south, it seems desirable to publish a description of the strata passed through. Up to November, 1915, the sinking to a depth of 730 ft. was visited periodically and the material examined. The war prevented further investigation until February, 1919, when sinking had been finished and roads had been driven out in the Thick Coal to two or three hundred yards from the shafts. A series of specimens that had been kept at the colliery were examined. These were not quite complete and of small size, but they served to identify the main sub-divisions. They showed that there are no sharp lines of demarcation between the various groups of strata, and that the Keele and the Corley beds are lithologically similar.

The shafts are 21½ ft. in diameter and 60 yards apart. No. 1, of which an abridged section is given below, is the southern shaft. It differs only in minor details from No. 2 Shaft.

No. 1 Shaft, Coventry colliery, Warwickshire Coal Company.

(Abridged from a section supplied by Mr. W. P. Evans, and notes in square brackets added to the original account.)

	Thickness.		Depth.	
Upper Coal Measures:—	Ft.	In.	Ft.	In.
Corley Beds—				
Red marls, sandy in part with occasional thin red and grey sandstones	98	5	98	5
Red sandstone and conglomerate [pellets of marl in a calcareous sandy matrix]	47	5	145	10
Red marls with thin sandstone bands	11	8	157	6
Hard red sandstone	20	6	178	0
Red marl	143	6	321	6
Red sandstone [purplish coarse sandstone with scattered pebbles] and conglomerate [dark-purplish sandstone-pebbles of Silurian age, and red and yellow cherts and white-grey limestone of Carboniferous age. Arley Exhall Conglomerate]	116	6	438	0

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	Thickness. Ft.	In.	Depth. Ft.	In.
Keele Beds—				
Red marland red and grey marl	55	8	493	8
Red and grey sandstone very jointy; pebbly in lower part [pellet bed]	25	1	518	9
Red sandstones with thin marls	209	9	728	6
Alternating beds of red marl and sandy marl ...	57	0	785	6
Grey sandstone [? *Spirorbis Limestone* of Longford Tileries]...	1	0	786	6
Alternate red marls, sandy marls and sandstones ...	146	0	932	6
Red and blue marls, sandy marls and sandstones; a little grey conglomerate at base with coal streaks, *Stigmaria and Sigillaria*	270	9	1,203	3
Halesowen Series—				
Brown and blue marl	46	9	1,250	0
Blue marly conglomerate 3 ft. 9 in. blue limy sandstone 3 ft.; green blue limestone 2 ft. 9 in. [fine calcareous sandstone] blue limy sandstone 1 ft.	10	6	1,260	6
Brown and blue marls and shales	81	6	1,342	0
Bastard blue limestone with ironstone balls [fine calcareous sandstone [? Index Limestone]	3	6	1,345	6
Blue and brown marls and blue shales	93	6	1,439	0
Coal -	0	10	1,439	10
Dark-blue shale with a little fireclay	23	8	1,463	6
Blue sandstone	56	6	1,520	0
Coal	0	4	1,520	4
Blue sandy shale with limestone-balls	43	8	1,564	0
Grey rock, flaggy in lower part	35	9	1,599	9
Coal, irregular contorted band	0	3	1,600	0
Dark fireclay and blue shales with ironstone-balls ...	19	0	1,619	0
Coal	1	0	1,620	0
Dark fireclay and blue shales with ironstone-balls ...	6	6	1,626	6
Coal and bass	0	6	1,627	0
Etruria Marls—				
Blue sandy fireclay and shale	11	0	1,638	0
Purple and yellow marl	7	0	1,645	0
Blue sandy shale 27 ft. 6 in., brown marl 1 ft. 3 in.; fine-grained blue sandstone 16 ft. 3 in., multicoloured sandy shale 1 ft. 9 in....	46	9	1,691	9
Blue sandstone with irregular bands and pockets of brown-grey conglomerate [Espley Rock] and brown and blue sandy shale	33	9	1,725	6
Blue, brown and yellow marl	22	0	1,747	6
Grey rock [Espley Rock] with shale and fireclay nodules	16	6	1,764	0
Yellow and brown fireclay and grey sandy shale ...	17	0	1,781	0
Middle Coal Measures:—				
Grey rock	47	0	1,828	0
Grey fireclays and shales with some ironstone ...	95	0	1,923	0
Coal	1	6	1,924	6
Grey shaly sandstone	45	0	1,969	6
Coal 2 ft. 5 in.; coal and dirt 9 in.; coal 1 ft. 9 in. [Four Feet Coal]	4	11	1,974	5
Grey sandy fireclays and shales with ironstone-balls [4 ft. 6 in. of black shale at 2,014 ft. may represent the ? "Marine horizon" of the boreholes]	118	3	2,092	8
Blue shale with ironstone-bands—"Ragged Stone" Ironstone Measures	18	9	2,111	5
Black shale	1	9	2,113	2
Thick Coal { Coal—Two Yard Coal	5	4		
Holing dirt	0	4		
Coal—Ryder and Ell Coals [no visible parting] ...	9	11		
Holing dirt	0	1		
Coal—Slate Coal	6	0	2,134	10

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	Thickness. Ft.	In.	Depth. Ft.	In.
Holing dirt	1	2	2,136	0
Coal—Lady Coal	1	8	2,137	8
Dark fireclay and grey sandy shales with ironstone-balls [White Ironstone Measures]	26	10	2,164	6
Coal—Seven Feet Coal	3	4	2,167	10
Brown and grey fireclay with ironstone-balls... ...	4	2	2,172	0

The belt of sandstones and conglomerate at 438 ft. may be matched perfectly with the exposures at Arley station, and at Exhall. Here, as elsewhere, they form a convenient base to the Corley Beds, though the rocks above and below them are of similar aspect.

In the Keele Beds the nodular Spirorbis limestone (probably equivalent to that of Maxstoke) found near the top of the series in the two borings was not recognised in the shafts, but the "grey sandstone" 1 ft. thick at a depth of 786 ft. in No. 1 probably represents the Spirorbis limestone that occurs about 400 ft. above the base of the Keele Beds at the brickpit by Longford station. It will be noticed that there is a greater development of sandstone above this horizon at the shafts than in the borings.

The Etruria Marls maintain the same thickness as near Nuneaton, but are mainly grey in colour, though a few thin beds of typical purple and mottled marls are present in addition to Espley Rocks.

The measures between the base of the Etruria Marls and the Thick Coal call for little remark.

The Thick Coal is said to be of good quality. The "Spires" (a rather dull compact coal of good quality) of the Ell seam are present as usual, and in places the Slate Coal takes on in part a "spiry" character with a small development of bastard cannel. The Ell and Ryder together vary from 10 to 11 ft. in thickness. The inferior coal known as the Bare Seam, which elsewhere occurs between the Two Yard and Ryder coals, appears to be absent, but the pea-like "Ryder stone" occurs in thin lenticles near the base of the upper seam.

Near the shaft the seam suffers from slight rolls, and is split in places by irregular partings of hard white micaceous sandstone a few inches in thickness, which have the appearance at first sight of intrusive white trap.

Water from fissures proved a serious obstacle to sinking. Down to 180 ft. the flow amounted to 500 gallons per minute. This was shut off by coffering. The sandstones and conglomerates at the base of the Corley beds yielded 2,600 gallons per minute in both shafts, and were shut off by cast-iron tubbing. On resuming sinking, water again proved troublesome, and the cementation-process for stopping the fissures was adopted with great success.

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APPENDIX IV.

Note on the Lower Greensand in the West Bilney Borehole, Norfolk.

By J. Pringle.

This borehole, made in 1918, is situated 4/5 of a mile south of West Bilney, about six miles south-east of Kings Lynn. It commenced in superficial deposits at an estimated height of about 20 ft. above O.D., and, after passing through the Lower Greensand, entered Kimmeridge Clay at the depth of 130½ ft. In a brief account of the latter formation published elsewhere,[1] the details of the Lower Greensand were not set forth: these are as follows:—

	Thickness. ft.	in.	Depth. ft.	in.
Superficial deposits	19	6	19	6
Light-brown and silvery sands	74	0	–	–
Blue sandy clay, not examined	0	6	–	–
Hard glauconitic sandstone with small brown phosphatic pebbles	0	4	–	–
Soft incoherent glauconitic sand	2	0	–	–
Brownish-green glauconitic sandstone with fragments of lignite	0	10	–	–
Dark-brown fine-grained glauconitic sand with small patches of white sand	5	0	–	–
Hard dark-brown glauconitic grit with irregular fragments of compact fine-grained brown sandstone ..	0	6	–	–
Soft dark-grey glauconitic sand with fragments of lignite	21	10	–	–
Grey sandy limestone with numerous small well-rounded black phosphatic nodules, some enclosing shell-fragments. Iron pyrites plentiful in matrix ...	2	0	–	–
Dark-brown fine-grained glauconitic sand	4	0	130	6
Kimmeridge Clay	153	8	284	2

The uppermost part of the section is based on the cores obtained from a second borehole situated a few feet away from the earlier hole. It is likely that the whole of the sands belong to the Sandringham Sands, which are said to be probably over 100 ft. thick.[2] There was no sign of the Snettisham Clay. According to the bore-record a hard grey sandy limestone, full of well-rounded black phosphatic nodules, was passed through 4 ft. above the base of the formation. This limestone is evidently a basement-bed, and its position as recorded may be due to an accidental reversal of the cores before the journal was made.

---

[1] 'Special Reports on the Mineral Resources of Great Britain,' *Mem. Geol. Surv.*, vol. vii, 2nd ed. (in the press), p. 37.

[2] 'The Geology of the Borders of the Wash,' *Mem. Geol. Surv.*, 1899, p. 5.

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APPENDIX V.

Glauconite-sand in Borings near Lewes, Sussex.

By Sir A. Strahan, K.B.E., etc.

A boring, recently been made by Messrs. Duke and Ockenden at Iford, near Lewes, started in alluvium, and after passing through a few feet of Lower Chalk, penetrated the Upper Greensand and Gault, the section as supplied by the borer being as follows:—

	Thickness. Ft.	Depth. Ft.
Marl and gravel	25	25
Rock and clay	11	36
Clay	289	325
Black sand	5	330
Sand	4	334

Water overflows at 180 gallons per hour. Rest level 21 ft. above surface. The height of the surface is about 30 or 35 ft. O.D.

The "black sand" at 330 ft. depth consists almost wholly (upwards of 99 per cent.) of grains of glauconite. The grains are of rounded or subangular outline, averaging 0·2 mm. in diameter and are loosely held together. This glauconite-sand, which appears to be unique in Britain, is being made the subject of further examination. It differs from the glauconitic rock of Ebbsfleet, described in the 'Summary of Progress' for 1911, pp. 72, 73, in the respect that the glauconite in that rock formed a cementing matrix in which quartz-grains were embedded.

A boring now in progress, midway between Plumpton and Plumpton Station and 5½ miles N.W. of Iford, has reached the same glauconite-bed under 130 ft. of Gault. The rock is not conspicuously granular, but appears to be made up to the extent of about 90 per cent. of glauconite in a finely divided state, with an admixture of rounded grains of quartz and some argillaceous material. It is 4 ft. thick.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1920.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1920.

I.—INTRODUCTION.

By J. S. FLETT, M.A., D.Sc., LL.D., F.R.S.

During the year 1920 changes on the staff of the Geological Survey were exceptionally numerous and important. In July Sir Aubrey Strahan, Director, and Mr. G. W. Lamplugh, Assistant Director (for England and Wales), retired after completing their service; Dr. Flett (Assistant Director for Scotland) was appointed Director, and Mr. J. Allen Howe (Curator of the Museum) became Assistant Director in Mr. Lamplugh's place. Dr. Walcot Gibson was promoted Assistant Director for Scotland in succession to Dr. Flett, and proceeded to Edinburgh in November. Dr. McLintock, of the Royal Scottish Museum, formerly a member of the staff of the Museum of Practical Geology, was appointed to succeed Mr. Allen Howe as Curator, but did not take up his duties before the close of the year. The staff was expanded by the appointment of six geologists, and Mr. Henry Dewey and Mr. Bernard Smith were appointed District Geologists.

It was decided to begin the revision of the maps of some of the more important districts of the North of England, and to open local offices in Newcastle-upon-Tyne and in Whitehaven. Mr. R. G. Carruthers is to take charge of a field-unit, comprising four geologists, in the Northumberland and Durham district, and Mr. Bernard Smith is to superintend the work of a similar unit in Cumberland and Westmorland. By the close of the year a start had been made in the work of organising these new field-units.

In England and Wales during 1920 work was continued in all the districts in which mapping had been in progress before the war, viz., the London district under Mr. R. G. Carruthers, the Warwickshire and Staffordshire district under Dr. Walcot Gibson, and in Shropshire under Mr. T. C. Cantrill. At the same time it

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was necessary to continue the investigation of the country's resources of economic minerals, which had been in progress during the previous six years, in order to complete the series of Special Reports on the Mineral Resources of Great Britain, inaugurated by Sir Aubrey Strahan, which had proved so successful. Of these the principal were a series of reports on the lead and zinc ores of England and Wales, on copper ores, and on salt deposits. At the close of the year these reports had been completed in manuscript, and were in the press or being edited for publication. Several reports on iron ores, arsenic, fireclays and siliceous refractories were published during 1920, and new editions of the reports on silica rocks and on cannel coal, mineral oil, etc., in England were issued. In all these cases a certain amount of field-work had to be done to bring the information up to date.

In Scotland field-work was continued in all the districts which were in hand before the War, viz., Ayrshire, the Central coalfield (with Clackmannanshire), Mull and the adjacent islands, and Sutherlandshire, but part of the time of the staff during the summer was taken up with special enquiries. Mr. Wilson has prepared a report on the lead, zinc and copper ores of Scotland, which involved much field-work. Dr. Lee has begun a revision of the Secondary rocks of the Brora coalfield, with especial reference to the correct determination of the palæontological zones. Mr. Macgregor has edited a report on the iron ores of Scotland, which was published during the year.

In the London district Mr. Carruthers and his staff have been at work principally in the Lea Valley, and near Crayford and Erith on the south side of the Thames. Several points of interest have been added to the information available. The Reading Beds of Collier's End show great lateral variation, which may indicate that they are unconformably overlapped by the London Clay. Near Swanscombe the Blackheath Beds are exceedingly thin, and may, indeed, be absent in places; but near Shorne they have a thickness of about 20 ft., and are apparently of normal character. The terraces of the Lea Valley have been the subject of careful study.

The Swanscombe gravels, which yield many palæolithic flint implements, are divisible into a 100-ft. terrace, and the 50-ft. deposits, of which the latter apparently form a continuous series down to the bottom of the buried channel of the Thames.

In the Midlands district (Warwickshire and Staffordshire) the solid rocks surveyed are Cambrian, Silurian, Carboniferous and New Red. A small area of the quartzite of the Lickey Hills, near Rubery, enters the Birmingham Sheet, but it has not been proved to contain fossils, and is presumptively of Lower Cambrian age. Of the Silurian rocks of this district the Upper Llandovery is represented by a fossiliferous sandstone near Rubery village. The Wenlock strata which follow, especially those of the Wren's Nest, Dudley, are well known to all geologists. They comprise the Wenlock Shales and Limestone, long quarried and now

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mined. Above these the Ludlow Shales and the higher Silurian up to the horizon of the Ledbury Passage Beds have a fairly extensive development within the area surveyed during the year, especially around Turner's Hill and Ellowes Park. The Upper Carboniferous of the Dudley district comprises the Etruria Marls, the Keele Beds and the Hamstead Beds, of which the last-named contains a limestone-breccia, or calcareous conglomerate. Near Halesowen the Halesowen Sandstone contains Spirorbis limestones and three seams of coal which are not workable. The Keele Beds and Hamstead Beds, which occupy the top of the Carboniferous succession, are very typically developed, and seem to be quite conformable throughout.

The Bunter and Keuper of Newport (Salop) present some features in common, but are, on the whole, well-characterised and distinct. An unconformability probably occurs between them, but its significance is at present impossible to estimate. In the Birmingham area the Upper Mottled Sandstone assumes great importance, and has served as a source for moulding sands, which are of high reputation.

The Glacial deposits of the Midlands in the vicinity of Newport and Birmingham, though they have been very minutely investigated by many local geologists, continue to furnish results which are of great interest as a record of the closing stages of the Glacial period. Around Newport sands and gravels were deposited as series of fans, the different series marking successive positions of the ice-front. Apparently there are no terminal moraines. Eskers trending at right-angles to the ice-front connect corresponding fans in the several series. At a later stage an extensive lake covered the area up to the 300-ft. contour. Its shore-line is shown in places by terraces, but as a rule merely by a notch.

Although systematic mapping has not yet been begun in the Whitehaven district, Mr. Smith has had opportunity of examining the cores of certain bores that have recently been made. He finds that these indicate a remarkable change in the character of the Carboniferous Limestone in the vicinity of the boundary fault of the exposed Whitehaven coalfield. This was not wholly unexpected, as the surface indications had suggested a similar conclusion; but it is evident that when the mapping has demonstrated the conditions in the exposed coalfield, and further boring has taken place, important results may be anticipated.

In Scotland the field-staff were engaged during most of the summer in the primary 6-in. survey of the Highlands. New light has been thrown on the geology of Iona by Mr. Anderson, who finds that the island consists of a platform of Lewisian Gneiss overlain by Torridon sediments. In the Lewisian there are rocks of igneous, and others of sedimentary origin; among the latter are the well-known Iona marble and dark graphitic schists. Intrusive masses of epidiorite and pegmatite traverse the gneisses and schists. The basal conglomerate of the Torridon is, in

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places, intensely crushed, but the common boundary of the two series is not regarded as a thrust-plane. Dykes of basalt and lamprophyre intersect the Torridon strata, and the Newer Granite of the Ross of Mull possibly produces contact alteration in these sediments.

A very interesting section at Gribun, in the Island of Mull, has now been investigated for the first time since Professor Judd described it in 1878. Many fossils have been collected, and have been determined by Dr. Lee. Trias and Rhaetic rocks form the basement, the latter yielding characteristic fossils. Broadford Beds follow (Hettangian and Sinemurian) containing well-preserved fossils, and Cretaceous rocks, including Cenomanian (Greensand). The whole sequence is interesting as affording one of the most important exposures of Secondary rocks in the island of Mull. In Ardnamurchan Mr. Richey has found a considerable outlier which is probably Inferior Oolite though it has a resemblance to Chalk.

The mapping of Mull has been completed, and the reports describe the usual variety of lavas and basic intrusions, with additional information on the Secondary rocks that underlie the volcanic plateau, and the Tertiary sediments among the lavas. The famous fossil tree of Burgh, which has been known for over a hundred years, has been very carefully described, and specimens of the fossil wood sliced for microscopic examination. Ardnamurchan, which is part of a Tertiary volcano of the same age as the mountains of Skye and Mull, has been visited by Mr. Richey, but the actual survey of the ground has hardly been begun. Staffa, famous for its basaltic pillars and caves, consists mainly of a single lava with its slaggy top covered by a thin layer of ash. One small, intrusive sill with clearly transgressive margins occurs below the base of the lava.

In Easter Ross the area surveyed consisted mainly of typical Moine gneisses intersected by lamprophyre dykes, and in the adjacent parts of Sutherland there are also granitic intrusions with allied basic masses which occasionally give rise to rocks of hybrid origin.

The igneous rocks which form the uplands around the North Ayrshire coalfield have been shown to include an extensive development of trachytic lavas overlain by basalts of Dalmeny type. These trachyte lavas may occur in two series, and are of interest because most of the trachytes of the West of Scotland have hitherto been believed to be of intrusive origin.

In Stirlingshire Mr. Dinham has brought to light an encrinital limestone which provides an important landmark in the correlation of the Carboniferous Limestones of Campsie with those of the Bannockburn district.

The Alloa coalfield of Clackmannanshire forms a link between the Central coalfield and that of West Fife. The revision is now in hand, and it is considered open to question whether the Barren Red Measures of the Upper Carboniferous occur in this area, as has hitherto been supposed.

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Extensive mining developments are taking place in the Douglas coalfield, and much new information is being collected especially from bores in progress. The revision of this district is proving of great interest, and resulting in a much more correct interpretation of the complicated structure of this coalfield.

Dr. H. H. Thomas has made an investigation into the petrographical characters of the foreign stones that compose the inner circle at Stonehenge, and arrives at the conclusion that they have been transported by human agency from Prescelly Mountains in Pembrokeshire, no doubt expressly for the purpose. This seems to set at rest a question which has long interested the antiquarian, and sheds an interesting light on the importance in which the building of Stonehenge was held by the early races of Britain.

II.—FIELD WORK.

(A)—ENGLAND AND WALES.

1. London and South-Eastern District.

H. Dewey, District Geologist.
R. L. Sherlock, D.Sc., A.R.C.S.
C. E. N. Bromehead, B.A.
R. W. Pocock, B.Sc.
T. Robertson, B.Sc.
} Geologists.

In the London District the mapping, which was suspended during the war, has been continued in an easterly direction on both sides of the Thames. On the southern side, Mr. Bromehead has surveyed the ground in Sheet 271 (Dartford) extending from Erith and Crayford to the margin of the map a mile or two east of Gravesend.

Dr. Sherlock has mapped in Sheet 239 (Hertford) the area extending eastwards from Hertford to Ware and thence down the Lea Valley to Cheshunt, and a small area in Sheet 221 (Hitchin) between Woodhall Park and Sacombe. Mr. Pocock and Mr. Robertson were engaged for a few weeks mapping the ground around Goff's Oak, Northaw and Cheshunt. Some parts of the North London map (Sheet 256) have been revised by Mr. Bromehead, especially the districts of Hampstead, Holloway, Stoke Newington, Bow, and West Ham, while Mr. Pocock has revised those of Watford, Bushey and Stanmore. The work was under the superintendence of Mr. Carruthers until his transference to Northumberland in October, when it was placed in the charge of Mr. Dewey.

CRETACEOUS.

The Chalk bordering the Thames between Erith and Gravesend has been mapped by Mr. Bromehead. It all belongs to the zone

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of *Micraster coranguinum*, as previously ascertained by Mr. Dibley.[1]

TERTIARY.

Dr. Sherlock records a section of abnormal Reading Beds at the south of Collier's End village (Sheet 221) in a disused brickyard. Below 8 ft. of lead-grey clay with brown mottling, which appears to be London Clay, there is a sharp plane of division. In downward succession it is followed by 3 ft. of black, somewhat silty clay, mostly stoneless, but with occasional flint-pebbles, some of which stand vertically. Most of the pebbles are black but some are yellow and others red, and a few are fragmentary. The black clay is local, being absent from a pit only 200 yds. to the west. The black bed passes down quickly, but with a sharp dividing plane, into 8 ft. of greenish-grey, sandy clay with indefinite crimson patches, which contains a few calcareous nodules. Below the clay is a stony mass of flints and flint pebbles resting on a piped surface of chalk, with the usual black or green-coated flints at the junction. Less than a mile to the east there is a 12-ft. pit in the typical fine white sand of the Reading Beds. These sections seem to indicate a rapid lateral change in the Reading Beds and an unconformable overlap by the London Clay, not previously noted in this part of the London Basin.

From Hertford to Great Amwell the Tertiary escarpment follows the right bank of the Lea, but to a great extent is buried under Drift deposits. Reading Beds, however, are visible in a pit situated in the small valley that extends from the east end of Hertford to Little Amwell. Here an 8-ft. section shows lilac silty clay, passing down into white sand with glauconite. At a higher level, behind Fox Hole Farm, an obscured brickyard appears to be in the London Clay. Across the gorge of the Lea, at Great Amwell, the Tertiary escarpment continues along the south side of the Ash, but here also it is buried under Drift.

At Great Amwell the Lea, having breached the escarpment, turns southwards and flows over the dip-slope of the Tertiaries. London Clay covers some square miles to the west of Broxbourne and Cheshunt and is mostly under plantations. On the east side of the Lea opposite Hoddesdon and Cheshunt there is a strip of bare London Clay between the river flat and the cap of boulder clay, but no sections exist on either side of the river.

In the area surveyed by Mr. Bromehead, the Thanet Sand and Woolwich Beds maintain their usual characters, but it is noticeable that Messrs. Priest and Stamp have detected fossils in the Bottom Bed near Swanscombe.[2] The same authors have described the Blackheath Beds of the Swanscombe outlier.

[1] 'Notes on the Chalk of the Medway Valley, Gravesend, etc.,' *Proc. Geol. Assoc.*, vol. xxix, 1918, pp. 68–105.

[2] 'Geology of Swanscombe Eocene Outlier,' *Proc. Geol. Assoc.*, vol. xxxi, 1920, pp. 187–199.

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These beds are so attenuated in this district that they were not indicated on the original 1-in. map. Even in the present 6-in. survey it has not been found possible to detect them everywhere; for example, on the west side of Swanscombe Wood the London Clay is shown as resting directly on Woolwich Beds. In the next large Tertiary outlier to the east, that of Shorne and Cobham, the Blackheath Beds reappear in force, at least 20 ft. of pebble beds and a few feet of sand being visible in sections. Here, therefore, this division has a development similar to that in the type area of Blackheath and Bexley. No cause has yet been suggested to account for its great attenuation in the intermediate area. The London Clay is the highest Tertiary formation in the district.

PLEISTOCENE.

In the area mapped by Dr. Sherlock the Chalky Boulder Clay with accompanying fluvioglacial sand and gravel covers most of the high ground. However, north of the Lea the Chalk rises to the surface between Woodhall Park and Sacombe, and the usually continuous sheet of drift is reduced to patches on the hill tops. The sand and gravel as a rule underlies the boulder clay and generally crops out in the slopes of the valleys, while boulder clay covers the plateau; but as the sand and gravel is in thick lenticles, it is absent in some parts and in others so thick that it extends on to the plateau. A large pit, south-east of Hertford, shows 5½ ft. of sand and gravel on 16 ft. of Chalky Boulder Clay, and below this about 14 ft. of sand and gravel resting on chalk. Here there is gravel above as well as below the boulder clay, and it seems probable that the clay is not the main mass, but a discontinuous band that appears sometimes below and sometimes within the gravel, as at Hertingfordbury, Watton-at-Stone, and the Ware section previously described.[1]

The fluvioglacial sand and gravel borders the Lea Valley on the western slopes from Hoddesdon to Cheshunt, and its level falls with the valley. South of the Lea, areas of clay with pockets of gravel are found on the top of the plateau at Little Amwell. They are characterised by the absence of the far-travelled pebbles, so common in the fluvioglacial gravels, and are composed mainly of flint-pebbles derived from Tertiary deposits. They contain also pebbles of white quartz and, occasionally, of Lower Greensand chert, both constituents being probably of Tertiary origin. With the gradual fall of the surface southwards the patches of clayey gravel become partially overlain by boulder clay, but they are always relatively higher than the adjacent fluvioglacial sand and gravel.

In the Lea Valley a terrace appears at Great Amwell. The northern boundary makes a feature extending across the valley and covered by fluvioglacial gravel probably marks a Reading

[1] 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, p. 31. Nos. 1 and 3 in the section there given are identical.

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Beds feature. The terrace has been followed along the west bank of the Lea southwards as far as Cheshunt. Excavations in its sand and gravel show sections identical with those in the fluvioglacial deposits. The difference between them is firstly, position; and secondly, as recorded at Hoddesdon by Mr. S. H. Warren,[1] the presence in the terrace gravel of flint implements. Brickearth covers parts of the terrace and has yielded bones of mammoth, reindeer and some other animals, and flint implements. It seems probable that the terrace may prove to be of Taplow age.

At Cheshunt small areas of blue and black clay are recorded by the nurserymen where one would expect gravel. So far no sections are available, but it is not unlikely that the clay is contemporaneous with the Arctic Bed found by Mr. Warren[2] at Ponder's End, lower down the Lea.

Mr. Bromehead finds that round Darenth Wood and Swanscombe Park there are patches of "Plateau" gravel. These consist of materials derived locally and from the south, and differ markedly from the gravel of Shooter's Hill, for which a Pliocene age has recently been claimed.[3]

The river-deposits of the Swanscombe neighbourhood had been carefully investigated by Messrs. R. Smith and H. Dewey previous to the survey.[4]

Although on the Essex side of the Thames the usual three terraces can be detected and were mapped by Mr. T. I. Pocock 18 years ago, on the south side there appears to be a continuous deposit from about the 50-ft. level to the bottom of the buried channel. This deposit is best known in the Crayford-Erith area, where many deep sections have been available for study. It will probably be found advisable to designate the river-gravels of the Dartford Sheet as the "Swanscombe" and the "Crayford" terraces, the former being equivalent to the Boyn or 100-ft., and the latter to the Taplow or 50-ft., and the Flood-plain terraces.

Besides the bedded river-gravels and brickearths, there are tumultuous deposits, found in several of the valleys tributary to the Thames, consisting of chalk-rubble, gravel and brickearth. These were evidently formed at a time when the topography was approximately that of the present day, since they occur along existing stream-valleys and depend for their composition on the strata bordering the valleys. Where Chalk crops out they consist of a rubble of chalk fragments, sometimes re-cemented, to which the term Coombe Rock has been applied; in the neighbourhood of Tertiary outliers they are brickearths

[1] *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, p. 225.

[2] *Op. cit.*, pp. 213–217.

[3] Leach, A. L., 'Supplementary Notes on Geology of Shooter's Hill,' *Proc. Geol. Assoc.*, vol. xxxi, 1920, pp. 127–132.

[4] *Archæologia*, vol. lxiv, 1913, pp. 177–204; vol. lxv, 1914, pp. 187–212.

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formed of re-sorted Tertiary material and with difficulty distinguished from those beds *in situ*; where patches of Swanscombe Terrace gravels occupy the high ground they are essentially gravels. The varieties of composition are so intermingled that it is impossible to map them separately, and it is proposed to include them under the term "Coombe Deposits." From the contained fossils and implements and from the manner of accumulation the period of formation appears to be the end of the Taplow stage, when the semi-arctic conditions of the Mousterian culture prevailed.

ECONOMICS.

The chief industry of geological importance is the manufacture of Portland cement. Along the river-bank from Stone to Gravesend chalk quarries for this purpose are almost continuous, and the operating companies are being forced to obtain their chalk from localities further and further inland. The Associated Portland Cement Manufacturers are also working the London Clay of Swanscombe Wood in a huge pit; the clay is made into slurry on the spot and piped to the works.

The Erith moulding sand (Thanet Sand) was worked extensively during the war, and the industry is still of great importance.

The Swanscombe Terrace gravels are largely dug for concrete-making and other purposes.

Over much of the area the Bottom Bed of the Woolwich Series is strongly impregnated with iron-oxide. There are some indications of an ancient "bloomery" working this ore in Lord's Wood, Green Street Green.

2. Warwickshire and Staffordshire District.

W. Gibson, D.Sc., District Geologist.
E. E. L. Dixon, B.Sc., A.R.C.S.
T. Eastwood, A.R.C.S.
T. H. Whitehead, B.Sc., A.R.C.S.
T. Robertson, B.Sc.
} Geologists.

During the past season, work in the Stafford Sheet (139) and in the north-western part of the Wolverhampton Sheet (153) has been continued by Messrs. Dixon and Robertson in the neighbourhood of Newport, Stone and Stafford. In the Dudley Sheet (167) Mr. Whitehead has mapped part of the mining district and its western border, lying between Tipton, Cradley and Kingswinford; while in the Birmingham Sheet (168) Mr. Eastwood has surveyed the south-western suburbs of that city and the ground extending westward towards Halesowen.

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CAMBRIAN.

The oldest rocks in the district examined by Mr. Eastwood are the Cambrian quartzites of the Lickey Hills, the northern portion of which falls, at Rubery, within the Birmingham Sheet. The mass consists of quartzite, similar to that of Hartshill, near Nuneaton. The beds strike approximately north-and-south, *i.e.*, parallel to the ridge, though the dip is very inconstant. Neither the top nor the bottom of the quartzite is exposed, and so far the quartzite has yielded no fossils; but on lithological grounds the Lickey Quartzite is regarded as of Lower Cambrian age and equivalent to the Park Hill and Tuttle Hill series of Warwickshire.

SILURIAN.

The Lickey Quartzite is succeeded unconformably by sandstones, varying from a grey-white compact rock, very like the underlying quartzite in appearance, to open-textured reddish sandstone, occasionally calcareous. The basal bed frequently contains boulders and pebbles of the underlying quartzite, as may be seen in the quarries on the south side of the main road in Rubery village. Casts of fossils are fairly abundant, and establish the age of the sandstones as Upper Llandovery. Up to the present, Tarannon Shales have not been found in this area, and the Llandovery Sandstone appears to be succeeded at once by shales, clays, and mudstones, with thin bands of limestone, and by compact sandstone, all referable to the Barr or Woolhope Beds of the Wenlock. The only section in them is that afforded by Callow Brook, the stream in the Asylum grounds at Rubery, where they pass beneath the Halesowen Beds of the Upper Coal Measures.

The outcrops of Silurian rocks at the Castle Hill and at the Wren's Nest, Dudley, and at Turner's Hill near Sedgley (Sheet 167) have been surveyed by Mr. Whitehead. Of these, the lowest beds occur in the cores of the Castle Hill and Wren's Nest domes, and consist of Wenlock Shales. These are followed by the well-known Wenlock or Dudley Limestone, which consists of two bands separated by flaggy and nodular limestones and mudstones. Both these bands have been almost completely quarried away at the outcrop, though mining for the limestone still continues. The Lower Ludlow Shales, consisting of mudstones with bands and nodules of limestone, succeed the Wenlock Limestones. At Dudley the area occupied by the outcrop of these beds has been found to extend farther south than is represented on the geological maps hitherto published. They occupy the surface in the allotments south-west of the Priory, near the Grammar School, and in the grave-yard of St. James's Church, Eve Hill. In an exposure in a ditch to the west of the Grammar School playing-field the dip is south-west, whilst to the east of the playing-field it is east or a little south of

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east, indicating an approach to the southern termination of the Wren's Nest dome.

Mr. John Hughes has supplied details of a shaft and bore-hole sunk within the site now occupied by the Dudley Union Workhouse. The following is an abstract of the section :—

	Ft.	in.
Measures to top of Fireclay Coal - -	54	4
Fireclay Coal - - - - - -	2	0
Rock, batt, clod, etc. - - - -	24	9
Bottom Coal (four coals with partings) -	10	0
Fireclays, binds, rock, etc. - - -	57	6
Mottled ground - - - - -	3	6
Red ground } Borehole - - - {	4	6
Red rock } Borehole - - - {	5	6
Red parting } Borehole - - - {	0	6
	162	7

It is possible that the mottled and red measures at the base of the section may be Ledbury Passage-Beds. If this is the case, the Aymestry Limestone must lie at no great distance from the surface between the Workhouse and the Wren's Nest. This section may be compared with that of the Trial Pits at Shaver's End, referred to by J. B. Jukes,[1] where 68 ft. of measures were found between the Bottom Coal and a blue clunch believed to be the top of the Silurian.

At Turner's Hill and Ellowes Park the following beds are exposed :—

6. Ledbury Passage-Beds.
5. Temeside Shales.
4. Downton Castle Sandstones.
3. Upper Ludlow Shales.
2. Aymestry Limestone.
1. Lower Ludlow Shales.

Of (1) only a small portion is poorly exposed in a little quarry on the west side of Turner's Hill. The Aymestry Limestone (2) is exposed in the same quarry, and contains the characteristic fossil, *Conchidium knighti*, represented by small individuals. The outcrop of the limestone extends only a few yards to north and south of the quarry, being truncated in both directions by faults. Both (3) and (4) are poorly exposed in the western scarp slope and near the summit of the hill; whilst (5) was recognised from the fragments ploughed up in a field immediately to the south-east of Turner's Hill Wood. A bed believed to be one of the Temeside Bone-Beds was found in place in the ditch forming the southern boundary of this field. In the adjoining field to the south large fragments of highly micaceous, purple

[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, p. 83; also *Vert. Sect.*, Sheet 18, No. 36.

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and green sandstones belonging to the Ledbury Passage-Beds (6) were found, thrown up by the plough. The Passage-Beds crop out in Ellowes Park also, and are well exposed in an east-and-west stream-course near Ellowes Park Farm.[1]

CARBONIFEROUS : COAL MEASURES.

Near Dudley, on the western margin of the South Staffordshire coalfield, the delimitation of the outcrops of the Middle Coal Measures, and of the various members of the Upper Coal Measures, has been continued by Mr. Whitehead.

The Etruria (Old Hill) Marls occupy the higher ground around Brierley Hill and Scott's Green, and are brought in by the Brierley Hill fault-trough. They also extend northward along the western margin of the exposed coalfield from the junction of the Brockmoor and Western Boundary faults at Brettell Lane nearly to Straits Green, the boundary of their outcrop to the east being determined largely by the Brockmoor and Shut End Faults. In general the Etruria Marls of this part of the coalfield appear sandier, and the marls of a duller purple colour, than around Old Hill and Oldbury.

The Halesowen Beds are nowhere preserved in the area surveyed, with the possible exception of some coarse greenish sandstones exposed in the brook north of Conqueror's Farm, Straits Green. If, as their characters suggest, these beds belong to the Halesowen group, they must be bounded on all sides by faults, as they abut, on the west against the upper portion of the Keele Beds, and on the east against the Middle Coal Measures.

The Keele Beds occupy the eastern half of Himley Park, and near the Straits form a shelf-like feature between the high ground formed of the Hamstead Beds to the north-west and the Western Boundary Fault to the south-east. They consist chiefly of red marls and sandstones, a 'pellety sandstone' or limestone breccia (conglomeratic cornstone) occurring in the cutting of the mineral railway in Himley Wood. There are at present insufficient data to determine what proportion of the Keele group is present at the outcrop in this area, or to establish the local thickness of the group.

Hamstead Beds.—These beds,[2] consisting of a lower Calcareous Conglomerate Group and a higher Breccia Group, occupy a strip of ground extending from near Kingswinford to Brettell Lane. The outcrop is bounded on the east by the Western Boundary Fault, and is separated from the Trias on the west by another fault. Only one band of calcareous conglomerate is recognisable, of which exposures occur north of Bromley Lane and near Buckpool. Another area of the Calcareous Conglomerate Group, with three conglomeratic horizons, comes in

[1] W. W. King, *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, pt. 2, 1917, p. 92.

[2] W. W. King, *Quart. Journ. Geol. Soc.*, vol. lv, 1899, pp. 112–115.

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above the Keele Beds near the Straits, and the examination of these, together with the overlying Breccia Group, has been begun around Baggeridge and Gospel End.

North of Halesowen, in ground mapped by Mr. Eastwood, a small tract of highly-inclined Middle Coal Measures, including members of the Thick Coal, with the Gubbin Ironstone and the Heathen Coal, is being worked by a day-hole at Cockshot Lane, south-west of Blackheath. The ground is obscured by drift, and apart from the small coal-workings there are no exposures, though it is evident, since the Halesowen Beds come on east of Cockshot Lane, that a fault, described by Jukes as the Russell's Hall Fault, must intervene, as shown on the old 1-in. map (62 S.W.). The succession as far west as the Dudley canal is regarded as normal—the strata exposed at Coombes Wood Tube Works are believed to belong to the base of the Etruria Marls—though another fault, with a westward downthrow, may come in beyond, introducing beds half-way up in the Etruria Marls.

South of Halesowen there has been no exploration in the concealed coalfield since the Manor Pit was abandoned many years ago. The coals are believed to deteriorate rapidly in a southward direction.

The Etruria Marls call for little comment. Beds high in the succession are exposed in the brick-pits north-east of Halesowen station, where they consist of the usual dull-red marls and conglomerates (espley rocks), with occasional thin bands of coal. Good sections in espley rocks may be seen on Mucklow Hill, where the Russell's Hall Fault brings them against the Halesowen Sandstones.

The Halesowen Sandstones consist of sandstones interbedded with clays and shales, including thin seams of coal and at least two bands of Spirorbis limestone. When fresh, their prevalent colour is grey, though the sandstones usually weather buff or brown and are occasionally stained red, while the argillaceous beds range from white to almost black. The beds are sometimes olive- and chocolate-coloured, especially at the base and near the top of the group. The sandstones are occasionally both pellety and pebbly; the latter condition is especially marked in the basal sandstone, which in places so closely resembles an espley rock of the Etruria Marls that it is difficult to distinguish between the two groups.

The Spirorbis limestones of this group are grey or dirty white in colour, in contrast with the blue and blue-grey limestones of the overlying Keele Beds. The lowest limestone in the Halesowen area was at one time worked about 400 yds. east of Manor Farm, and apparently occurs as a flaggy band, 8 ins. to 1 ft. in thickness, immediately above a bed of sandstone. The same band is represented by debris on a dump from an air-shaft to the canal-tunnel at Lapal House, Moor Street. Its position in the Halesowen group is about 100 ft. above the base. During the excavation of the sewers for some new houses between Hayley Green

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and Hasbury (south-west of Halesowen) a similar bed was encountered. There *Spirorbis pusillus* was abundant and of unusually large size. In addition to the characteristic fossil, spines and scales of a fish of Acanthoid type are present, along with fragments of coal.

Higher in the succession, and probably not more than 150 ft. below the top of the Halesowen group, is another Spirorbis horizon. This may be seen *in situ* in a little tributary 300 yds. south of Illey Mill. The limestone is an 8-in. band of compact rock lying in a thin belt of clays between two sandstones, the lower of which is exposed in the brook by Illey Mill. Although the rock as a whole is compact, it is frequently made up of fragments of white limestone set in a matrix of grey limestone of equal hardness. *Spirorbis* is not abundant, but it occurs in both matrix and fragments. The locality mentioned above was first discovered by Dr. W. Gibson, and was afterwards described by the late Prof. Lapworth. During the past season, pits yielding fragments of similar limestone have been discovered between Illey Brook Farm and Illey Hall Farm. What is believed to be the same bed occurs in place in a ditch 200 yds. north-east of Warstone Farm near Lower Illey.

Several seams of coal occur in the Halesowen group, but as a rule they are very thin and impersistent. Attempts to work one or other of them have been made at the northern end of Offmoor Wood (Sheet 167); also near Rubery, and at California, but without success.

Sections in various portions of the sequence may be seen in the streams flowing northwards near Halesowen; but east of that town much of the ground is obscured by drift. Near Rubery, intermittent sections showing sandstones, clays, and coal, may be seen in the stream at Balaam's Wood, and in Callow Brook in the Asylum grounds. Recent excavations at the north end of the Asylum (Rubery Hill) exposed a seam of coal about a foot thick, associated with grey clay containing small fragments of fossil wood, and dipping westward off the Llandovery Sandstone.

The red rocks succeeding the Halesowen Sandstones and unconformably overlain by the Trias were originally classed as 'Permian of Salopian type.' In the South Staffordshire district, as in other areas in the Midlands, it is becoming increasingly clear that the whole of these beds must be relegated to the Carboniferous System. They consist of argillaceous and arenaceous sediments in which red is the prevailing colour, and the lower portion is characterised by occasional bands of bluish Spirorbis limestone. It is to this group that the name Keele Beds is applied.

The junction of the Keele Beds with the Halesowen Sandstones appears to be conformable, and the base is frequently marked by sandstones of dark lavender tint, such as are seen in Breach Dingle, near Romsley. These are succeeded by red

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marls and sandstones with thin bands of bluish limestone containing occasional specimens of *Spirorbis*. The band found by Mr. Cantrill[1] near Wassel Grove and believed to be about 50 ft. above the base of the group has not been located in the Romsley area. Another band, about 350 ft. above the base of the group, first discovered by Mr. Cantrill (*op. cit.*) near Offmoor Wood, may be seen in a fragmentary condition in a gully 200 yds. north-east of St. Kenelm's Hall, and in Breach Dingle at a point 400 yds. north-north-east of St. Kenelm's Rectory, while it is abundantly represented in the debris from the pipe-line of the Birmingham aqueduct (Elan supply) at the south-east corner of Offmoor Wood. What is possibly the same band has been recorded at Frankley reservoir, and it has since been seen in Egghill Dingle, Long Kettles Wood, near Gannow Green, at Hollymoor Asylum, and near Bartley Green.

Hamstead Beds.—Higher in the succession, the marls occasionally take on an even brighter red tint than usual, whereas the sandstones, although often red, are frequently brown or yellowish. In addition to change of colour these sandstones locally become markedly calcareous and highly charged with small rolled pellets of inorganic limestone, in addition to which occasional small fragments of organic limestone, calcareous mudstone, and other foreign matters occur. In the past these conglomeratic 'cornstones' were burnt for lime. Though similar rocks are found in the Keele Beds below, the position and general characters of the main belt of these calcareous sandstones link them up with the limestone conglomerates of the Hamstead Beds, found farther north at about the same position in the sequence.

Though the Hamstead Beds, which occupy an intermediate position between the Keele Beds and the trappoid breccia of the Clent Hills, are well exposed in natural sections near Romsley, they make much more striking features around Frankley, where they are surmounted by a capping of breccia—the outlier of Frankley Beeches.

The Clent Breccia has been so well described by Mr. Wickham King[2] that there is little to add here. Up to the present the evidence is in favour of general concordance between the breccia and the beds below, while the relation between it and the overlying Trias is one of marked unconformity.

Though giving rise to prominent features, it is, as a rule, not well exposed, especially in the main mass forming the high ground extending from the Clent Hills to Rubery. In the detached areas good road-sections are to be seen at Merritt's Hill near Northfield, and in the Halesowen-Birmingham road east of Quinton. In addition to the localities already known, a small outlier of the breccia has been found north-west of Bromwich

[1] *Geol. Mag.*, 1909, p. 449.
[2] *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 97.

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Wood, between Frankley and Bartley Green. It is about 400 yds. in length by 200 yds. in breadth, and probably does not exceed 20 ft. in thickness. Though there are no sections in it, the ditches and the debris on the ploughed fields afford ample evidence of the presence of breccia.

TRIAS.

In the district of Newport (Salop) Mr. Dixon finds that, as elsewhere, the several lithological types on which the original classification of the Trias was based are not rigidly confined to the subdivisions named after them. Thus, mottled and brick-red soft sandstones, devoid of fragments of old rocks, and indistinguishable from the beds that make up the Lower and Upper Mottled subdivisions of the Bunter, are found also in the Pebble Beds and in the Keuper Sandstones. Thick beds of massed pebbles are certainly confined to the Pebble Beds; but scattered pebbles, and, more especially, subangular fragments of hard rocks, occur in the higher part of the Lower Mottled subdivision, and still more frequently in the Keuper Sandstones. The same features characterise special lithological types. In parts of the Midlands, fresh pink felspars, in the form of small worn crystals and cleavage-fragments, distinguish the base of the Keuper Sandstones from higher zones and also from Bunter beds; but near Newport such felspar-fragments occur also at various horizons in the latter formation.

Notwithstanding a community of character, in this district Bunter and Keuper are quite probably unconformable. Fortunately the junction is exposed at several places along the bold feature caused by the erosion of the soft Upper Mottled sandrock below the hard Keuper sandstones; in all sections it is either obviously or possibly sharp, and in some is uneven. Also the base of the Keuper is usually conglomeratic, though the fragments may be scattered sparsely along a single line. It has not been possible to determine variations in the thickness of the Upper Mottled formation, but that of the Keuper Sandstone varies from about 20 ft. near Broad Hill, east of Newport, to 400 ft. west of Blymhill; while a boring for water now being put down near Ivetsey Bank has proved 600 feet without reaching the base. The thinning near Newport may be due to overlap of basal members, present at Blymhill and Ivetsey Bank, by higher members, in which case the base, in places at least, is unconformable. Further evidence, however, is needed owing to an uncertainty as to the significance of variations in character and thickness in 'continental' formations such as these, and the known frequency and persistence of horizons of contemporaneous erosion in such formations.

Near Stone, Mr. Robertson finds that the Bunter Pebble Beds with their pebbly sandstones cover the area around Swynnerton, with the exception of a narrow band of Keuper

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Sandstone and Marl, thrown down along the eastern side of the Apedale Fault. Another fault, running east-north-east through the middle of Swynnerton Park and thence by Darlaston and Oulton to Moddershall, throws down Keuper Marl to the south. An inlier of the Keuper Sandstone occurs in the valley of the Scotch Brook, north-east of Stone.

A strip of Pebble Beds runs south-east from Moddershall to Cotwalton. Here, as to the north, in the Stoke-on-Trent Sheet (123), the Pebble Beds seem to be directly overlain by Keuper Marl.

From Swynnerton Park for 8 miles southward to Haughton, dark red and purple Keuper Marl, usually without skerry-bands, is the only 'solid' rock to be seen. Except close to the boundary-fault at Swynnerton Park it is practically horizontal. Good exposures are visible in many places, the higher ground being for the most part free from drift.

Butterton and Swynnerton Dyke.—It has long been known that an igneous dyke cuts the higher parts of the Coal Measures on the southern margin of the North Staffordshire coalfield and extends southwards through the Triassic rocks to the west of Stone.[1] In the southern part of its course this dyke has now been traced in detail by Mr. Robertson from Swynnerton to Heamies Farm near Norton Bridge—a distance of about 3 miles. Its approximate position was detected on Pebble Bed ground just north of Swynnerton village. Thence it bears a little east of south, past the west side of Swynnerton Hall and through Swynnerton Park. Halfway through the park the outcrop is shifted about 150 yds. to the east-north-east, just where the fault already mentioned as throwing down the Keuper Marl is estimated to cross the ground. Whether this shift is due to a displacement of the dyke by the fault or to a diversion of the dyke along the fault is not known.

A short distance north of the fault a poor exposure in a coppice shows the dyke in contact with and enclosing pieces of Pebble Bed (Bunter) sandstone. In Doles Coppice, 150 yds. south of the fault, the dyke (or one branch of it) is 3 to 4 ft. thick, seems to be nearly vertical, and is seen in contact with Keuper Marl.

South of this point the dyke-outcrop traverses no other formation. It appears to run undisturbed to Pilsen's Wood, west of the Highlows, where in one place it has broadened out to an estimated width of over 100 yds. Some of the hand-specimens obtained here exhibit a much more coarsely crystalline texture than any noticed farther north. There are also exposures of much-decomposed material a short distance south of the wood. Nothing more of it is seen *in situ* until we reach the north side of the hill on which Heamies Farm is situated. Here three distinct branches of the dyke are visible, approximately in line

[1] 'The Geology of the Country round Stoke-upon-Trent' (*Mem. Geol. Surv.*), ed. 2, 1905, p. 55.

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with the exposures farther north. Each of these branches is 3 to 4 ft. in thickness, with a very steep dip to the west. The most easterly and most westerly branches are respectively about 24 ft. and 240 ft. from the middle one. South of this point the dykes either thin out or cease to be traceable.

West of the South Staffordshire coalfield, from Wordsley to Himley, Mr. Whitehead finds that the Trias outcrop is divided into irregular blocks by a system of faults that would seem to be the result of adjustments accompanying, or following, the movement along the Western Boundary Fault. A borehole for water at Stourbridge Workhouse,[1] begun in the Upper Mottled Sandstone, reached the Pebble Beds at a depth of about 130 ft. As the base of the Pebble Beds on Cooknell Hill, to the south, is well over 300 ft. above sea-level, it is clear that, immediately to the south of the workhouse, there is a fault that throws the Upper Mottled Sandstone on the north against the Pebble Beds and Lower Mottled Sandstone on the south. This fault appears to run westward to the Pebble Bed escarpment at Lawneswood, where it may join a north-and-south fault, with westward downthrow, known as the Stapenhill Fault. East of this fault, and south of the 'Workhouse Fault,' the ground is occupied mainly by the Pebble Beds, the Lower Mottled Sandstone emerging in small patches against the faults to the east and west. North of the Workhouse Fault, around Kingswinford, Wall Heath, and Himley, the Upper Mottled Sandstone occupies most of the area, the Pebble Beds emerging at the Ridge Hill, at Kingswinford, in Himley Park, and in small patches brought in by faults.

Both the Upper and the Lower Mottled Sandstone seem uniformly brick-red in colour in this district, the 'mottled' character appearing only when the passage into the Pebble Beds is approached.

The Triassic rocks examined by Mr. Eastwood in the Birmingham area consist of the Bunter Pebble Beds, the Upper Mottled Sandstone, the Lower Keuper Sandstone, and the Keuper Marls.

The Bunter Pebble Beds form a continuous belt between Smethwick and California near Harborne, but much of the ground is obscured by drift. From California southward nearly to Northfield they are cut out by a fault that brings in Keuper Sandstone against Keele and Hamstead Beds; but they come in again between the latter place and Rednal. On the north, shingle-beds are abundant; but on the south the bulk of the formation consists of soft red sandstone with occasional small pebbles.

The Upper Mottled Sandstone, which has furnished considerable quantities of moulding sand in Birmingham, may be seen at several places around Hockley and Summer Hill. Until just recently the sand was also obtained from a pit in Dale Street,

[1] Information from Mr. W. Wickham King.

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Smethwick, a locality much farther west than this formation is represented on the old 1-in. map (62 S.W.).

The Keuper Sandstone forms the higher ground of Birmingham and extends beyond the southern margin of the area mapped. Permanent sections are rare; but the formation may be seen in the canal-cutting south of the city, also near Weoley Castle, around Northfield, and in the Cofton railway-cutting. As a rule the sandstone is harder and browner than the Bunter, and can thus be distinguished from the rest of the Triassic sandstones; but in some cases red pellety sandstones similar to those of the Keele Beds render identification of poorly-exposed portions rather doubtful.

The Keuper Marl may be seen in numerous brick-pits to the east and south-east of Birmingham; but the actual junction with the Keuper Sandstone is not visible on account of a fault the existence of which has been proved by borings.

GLACIAL.

In continuation of the work commenced last year (1919) in the Newport (Salop) district, Mr. Dixon has found it possible to distinguish between the deposits of sand and gravel formed when the whole area lying below the 300-ft. contour was flooded beneath the waters of an ice-dammed lake and those earlier ones thrown down or laid bare as the ice-front retreated across the district. Last year some of the latter were attributed to escaping lake-waters. It is more probable that all the eskers and fan-like or delta-form deposits have originated in the ways suggested in the case of certain similar formations elsewhere, viz., that the fans and deltas have been thrown down along the ice-front at the mouths of englacial or subglacial streams during pauses in the retreat, and that the eskers show the courses of the streams. The eskers may have been formed at the mouths of the streams during the periods of more rapid retreat, or they may have accumulated in the stream-channels within the ice and have been merely bared by the retreat. The evidence obtained about Newport is open to either interpretation, but as regards the broad outline of the hypothesis it is unequivocal. The fans and eskers fall naturally into several linear series, each of which may be compared with a string carrying a few beads—the fans. With few exceptions any fan in a series is represented by a similar fan in each of the other series, and these similar fans are found to be so placed that the line connecting them, which according to the hypothesis gives us the position of the ice-front during their deposition, agrees with that position as inferred from the forms and orientations of the fans. Further, in several cases fans are bordered by hollows or by dry channels draining away from them, which seem to demand for their explanation torrents of water pouring off the fans.

The longest, widest, and most continuous of the series that have been recognised up to the present enters the southern

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margin of the area examined at Blymhill, 5 miles south-east of Newport, and follows a north-westerly course past that town, where it skirts the northern end of the high Bunter ground bordering the Coalbrookdale coalfield, to leave the area at Lane End, a run of 10 miles. This series, by its continuity and the obvious resemblance of two of the swellings along it to deltas or fans, gives the clue to the interpretation of the whole. Several small series run almost due west into it, or may be said to branch to the east from it.

The other bands that have been recognised, three in number, lie to the north-east of the major series, and parallel to it, the farthest removed following a line through Littleworth, High Offley, and Knighton (5 miles north-east of Newport). They pass up and down hill in the manner characteristic of eskers.

South of the latitude of Newport these minor series cannot be traced, and the swellings noticeable along the major series, indicative of pauses in the ice-retreat, are small and ill-defined. But at Aqualate Park, Newport, and thence east-north-eastward for 4 miles to Prospect Hill, Knightley, a line of fans in all the series points to a marked pause when the ice-front reached that line. At a mile or so to the north-west another line of fans shows that the retreat was stayed still longer when a line through Chetwynd Park and Littleworth was reached. The fan thrown down during this pause by the main stream is the largest and best example in the district. The alignment of the ice-front during this pause was appreciably more north of east than during the preceding pause. A third pause is marked by a line of smaller fans between Lane End and Knighton, and further swinging-round of the ice-front is proved by the north-north-easterly trend of the line.

Though the lines of fans mark stationary positions of the ice-front, they are quite unlike the 'terminal moraines' that have been recognised in various other regions. In fact it is noteworthy that the deposits at the stationary ice-front have been almost entirely localised to a few places where streams have debouched.

The ice-dammed lake that at a later period covered the area up to the 300-ft. contour has left traces of its shore-line in the form of terraces of sand and gravel, and, much more commonly, in a more or less marked notch or change of slope. Its western and northern limits have not been found; eastward it had a small overflow at Gnosall into the Trent basin. Deposits of laminated clay have been found at many places within its area, but appear to be connected with the fans of the earlier period previously described. They may have been laid down in small temporary sheets of water held up between the ice and the high ground during the retreat across the district.

North of Stone Mr. Robertson finds that the Trent valley is lined with boulder-clay, of unknown thickness, over which

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gravels rise to a height of about 30 ft. above river-level. Valley-gravels are well developed along the Trent and Sow valleys.

The Sow basin, north of Stafford, shows extensive stretches of gravel and sand, but very little boulder-clay. The broad pre-Glacial valleys have been nearly filled with sand and gravel brought down by the streams in late-Glacial or early post-Glacial times, when an enormous quantity of water was flowing. This sand and gravel collected in the side valleys also, *e.g.*, along Gamesley and Doxey Brooks. The modern shrunken rivers now run in approximately the same channels, but beyond the alluvium a slope, often steep, and sometimes 20 ft. or more in height, marks the edge of a sand and gravel terrace. These terraces are well marked along the Sow valley and are sometimes very persistent, *e.g.*, between Great Bridgeford and Stafford. The Sow now meanders over a flat peaty alluvial plain, beyond which on either side a bank of sand and gravel rises and masks with its irregular surface the contours of the original pre-Glacial valley.

An interesting channel, probably of glacial origin, is to be seen in the valley of Scotch Brook north-east of Stone. Just south of Oulton Mill the stream, which runs in a narrow steep-sided valley of Keuper sandstone, turns sharply to the west. About 200 yds. farther on it turns southwards again, round the end of a Keuper sandstone cliff. On the outer side of the first bend the valley widens out a little, and a series of clays, sands, and gravels has been deposited on the side of the sandstone slope to a height of about 30 feet above the present stream-level. There would appear to have been a block at this point, due either to the narrowness of the gorge below or to the fact that the valley beyond had not up till that time been excavated sufficiently deeply.

Overflow probably took place first of all due southward over the top of the sandstone barrier, behind which there is much gravel on the southern slopes. Finally, however, the gorge would be excavated sufficiently to allow the whole discharge to pass through it, leaving the sands and clays banked up at the side of the entrance.

No traces of drift have been found in that part of the South Staffordshire coalfield surveyed by Mr. Whitehead during the past season. To the west of the coalfield the most conspicuous drift feature is the 'esker' near Kingswinford, described by Prof. W. S. Boulton,[1] which extends, within the area surveyed, from Wordsley to Wall Heath. It forms in places a marked ridge. Exposures in it show sand and gravel, false-bedded, and sometimes contorted; with lenticles of clay, and streaks of carbonaceous material in places. In a sand-pit at Wall Heath, these sands and gravels may be seen resting on horizontal Upper Mottled Sandstone, the surface of which slopes westward at about 10°.

[1] *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, pt. 1, 1916, p. 25.

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South of the River Stour, and west of the gap made by that river in the Pebble Bed escarpment at Bell's Mill, south-west of Wordsley, a patch of sand, with lenticles of gravel containing many far-travelled pebbles, lies on the Lower Mottled Sandstone at the level of the adjacent canal. North-west of Himley, clay, or sandy clay, with many pebbles, occupies much of the higher ground, and is exposed to a thickness of about 15 ft. in a cutting of the new Wolverhampton Railway north-west of Himley Plantation.

The fields between Himley and Wall Heath are plentifully strewn with pebbles, of which a certain proportion consist of basalt, and of Coal Measure grits.

Much of the solid rock around Birmingham, in Mr. Eastwood's district, is obscured by drift. West of Warley and towards Halesowen the deposit is thin, and consists of clay and sand with some stones; but eastwards thick deposits completely hide the outcrops of the Trias. From Smethwick through Harborne to California the drift has a thickness of about 80 ft. Though the Glacial deposits are extremely variable, their general succession appears to be : (1) a lower series of tough reddish clays (as seen at California), associated with bedded sands and gravels; (2) an upper series of sands, clays, and loams, mainly unbedded. Far-travelled erratics occur in both series, and include many igneous rocks similar to those of the Arenigs; while of those from a less distant source the Rowley basalt is the most readily identified. Fragments of local sedimentary materials, such as espley rock from the Etruria Marls, and sandstone from the Halesowen and Keele Beds and from the Trias, are also common; while in the Longbridge area Lickey quartzite and Llandovery sandstone are present. The former wide-spread distribution of the drift is probably implied by the presence of erratic boulders over the Romsley area, though that district is now practically free from other forms of drift.

3. Shropshire District.

T. C. Cantrill, B.Sc., District Geologist.
R. W. Pocock, B.Sc. } Geologists.
D. A. Wray, B.Sc. }

During the past season the re-survey of Liverpool and its inner suburbs, begun[1] in 1914 but suspended during the war, has been completed by Mr. Wray. The whole of the Liverpool Sheet (96), with the exception of the area occupied by rocks older than the Coal Measures, has now been revised.

In the Wem Sheet (138) the south-western portion around Baschurch, Middle, and Leaton, has been finished by Mr. Wray, while Mr. Pocock has mapped a wide belt of ground between Wem and Hodnet.

[1] 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, pp. 11, 12.

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In the Shrewsbury Sheet (152) the north-western margin, traversed by the Severn between Shrawardine and Shrewsbury, has been examined by Mr. Wray.

TRIAS.

In the Liverpool district the 'solid' formations mapped by Mr. Wray are the Pebble Beds and the Upper Mottled Sandstone of the Bunter, and the Basement Beds and Waterstones of the Keuper.

Considerable modification of the original map has been necessary in some parts of the district. Thus the valuable information obtained during the construction of the new outfall sewer[1] from Walton to the Canada Dock fully confirms the original contention ('Summary of Progress for 1914,' p. 11) that the broad belt of Upper Mottled Sandstone shown on the old 1-in. map (79 N.E.) between Walton Hall and Sefton Park is not present. It has also enabled Mr. Wray to locate precisely the position of the main north-and-south faults that traverse the Triassic rocks of Liverpool; and also the base of the Keuper Sandstone, which was found to rest unconformably on the Bunter Sandstone in the tunnel-section under Oriel Road.

The Pebble Beds are well exposed in numerous old quarries at Everton, Aigburth, at West Derby, and also in the extensive cutting on the L. & N.W. Railway at Olive Mount. In the Liverpool District these beds are remarkable for their uniformity.

The Upper Mottled Sandstone consists of soft mottled yellow and red sandstone, and calls for little comment.

The Keuper Basement Beds, wherever exposed, have a gritty sandstone at their base. In the re-survey they have been met with in numerous places at the southern end of the city, and their outcrop has been found to be broken up by numerous parallel north-and-south faults, some of which are visible in the cuttings on the Cheshire Lines Committee's railway to the north of Toxteth and Harrington Docks.

The only exposure of the Waterstones is a narrow faulted outcrop in St. James's Cemetery.

In the south-western part of the Wem Sheet and in the north-western margin of the Shrewsbury Sheet, surveyed by Mr. Wray, it appears that, with the exception of about 2½ square miles on the east of Middle and the north of Pim Hill (an area almost free from drift) the 'solid' geology is largely obscured by a thick mantle of Glacial deposits.

The 'solid' formations mapped are the Bunter Sandstones, the Keuper Basement Beds, the Waterstones, and the Keuper Marl.

The Lower Mottled Sandstone was examined in sections alongside the River Severn at Ford, and also in the village of Ford, where it consists of thinly laminated and fine-grained red sandstones.

[1] The results of the examination of this section are published in *Proc. Liverp. Geol. Soc.*, 1915–1916, pp. 238–251.

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The Bunter Pebble Beds form an outlier at Benthall Cross and Whiston, about half a mile west of Ford. This outlier is shown on the old map (61 N.W.), but has been proved by sections exposed at Benthall Stone to cover a much larger area.

From what is known of the general structure of the district, the Pebble Beds should crop out beneath the broad covering of drift between Nesscliff and Pim Hill on the north, and Ford and Shrewsbury on the south; for the Lower Mottled Sandstone is exposed around Ford, and the Upper Mottled Sandstone on the lower slopes of Nesscliff and Pim Hill; but they were nowhere met with.

The harder beds that characterise the top of the Bunter and have been extensively quarried near Middle (at Webscott, Harmer Hill, and Pim Hill) strongly resemble beds met with in the Ruyton and Nesscliff districts farther west ('Summary of Progress for 1915,' p. 9). In like manner they give rise to a prominent feature in the landscape. They are, however, overlain by white and yellow sandstones, which appear to occupy the same horizon as the Grinshill freestones farther east, and to belong to the Keuper rather than to the Bunter. In the area about Middle the base of the Keuper has, therefore, been taken at the base of these yellow freestones.

It seems highly probable that the harder, dull-red freestones worked in the Ruyton and Nesscliff district represent not only these yellow freestones, but also part of the Upper Mottled Sandstone. As no definite line could be taken as the base of the Keuper at Ruyton and Nesscliff, the dull-red freestones have been mapped as a separate subdivision, and named the Ruyton Sandstones.

Through the whole area the Waterstones are represented by marly and flaggy chocolate-red and yellow sandstones, frequently characterised by small hollows or pores, of the size of a pin's head or of a pea. They are well exposed at Balderton Hall near Middle, and also near the National Schools and Shotton Hall, in the Harmer Hill district.

The Keuper Marl is well exposed in large disused marl-pits to the east of Lea Hall, Harmer Hill, and also at Newton on the Hill and Bilmarsh. At the latter locality it contains a prominent bed of sandstone.

The past year's work has tended to confirm the suggestion made in the 'Summary of Progress for 1915' (p. 9) that the Prees Syncline extends south-westwards to Ruyton and Nesscliff. It is highly probable that the country to the north and east of Baschurch is underlain, not by the Upper Mottled Sandstone, as is indicated on the old map, but by the Keuper Marl. The Keuper escarpment at Middle terminates very abruptly to the north, suggesting a faulted boundary, probably on the line of the powerful north-east and south-west fault well seen to the immediate north of Great Ness. The general effect is to bring the Upper Mottled Sandstone on the south-east against the supposed

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Keuper Marl on the north-west at Prescott, Fenemere, and Middle. The presence of abundant fragments of Keuper skerry sandstone in the drifts of the whole district to the south of Baschurch and Middle tends to confirm this view.

Around Pim Hill and Harmer Hill the structure is complicated by powerful north-and-south faults. One of these faults, which runs immediately east of Pim Hill, carries notable quantities of green copper ore, which was last worked about 50 years ago.

Farther east, the district of Clive, Grinshill, Lee Brockhurst and Hawkstone has been mapped by Mr. Pocock, who finds that all three divisions of the Bunter are present.

The soft, bright red and brown sandstones that form the upper part of the Lower Mottled Sandstone are exposed at Harcourt Park and Rock Hall, near Preston Brockhurst, where they are strongly current-bedded, and are cemented in places by barytes. At one horizon the sandstone is composed of well-rounded millet-seed grains.

The Pebble Beds form the high ground of Besford Wood, Booley, and Stanton, and have been quarried in places, on a small scale, for building-stone. Their base is marked by a bed of calcareous sandstone and conglomerate, which can be seen in the south bank of the Roden east of Lee Bridge, in the lane between Besford and Lee Bridge, and near Harcourt Park. Outliers of the Pebble Beds have been detected at Acton Reynald and Blaze Coppice, near Preston Brockhurst.

The Upper Mottled Sandstone is exposed on the southern slope of Grinshill, and forms most of the high ground at Weston Heath and Bury Walls (north-east of Lee Brockhurst) that was formerly mapped as Keuper Sandstone. No evidence has been found for the east-and-west fault shown on the map as running through Weston.

The upper limit of the Bunter is not well defined, but the line has been drawn to include all the red, fine-grained sandstones within the Upper Mottled division.

The succeeding Keuper Basement Beds consist of fine-grained yellowish to white sandstones, which have been extensively worked for many years at Grinshill as the well-known Grinshill building stone. The quarries show in places a vertical face nearly 100 ft. in height. Quarrying-operations have now ceased on account of the high cost of labour and the great thickness of marl and 'flag-rock' that has to be removed before the building stone is reached.

These white sandstones are well developed near the Red Castle and along the Terrace in Hawkstone Park.

The Waterstones are yellow, brown, and grey flaggy sandstones, evenly bedded, and for the most part of fine grain. They average 20 ft. in thickness at Grinshill, where they are known as the 'flag-rock,' and are used for rough walling and flags; at one time they were employed for roofing also.

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At the base of the 'flag-rock' there is a well-marked bed, averaging 9 in. in thickness, of yellowish sand with black specks of manganese, which is known as 'esk' or 'hess,' a local name for ashes. This bed has been found to persist throughout the area surveyed.

Good sections of the Waterstones and esk-bed are exposed near the obelisk in Hawkstone Park, and also near Marchamley.

The Keuper Marl is of the usual red and grey shaly type, with thin sandstones. The feature separating the outcrop of the Marl from the drift-covered area to the north-west, which was mentioned in the 'Summary of Progress for 1919' (p. 9), has been found to continue north-eastwards towards the Abbey.

The principal fault of the district runs north-eastward through Preston Brockhurst and Lee Brockhurst, throwing down the Keuper Marl on the north-west against the Bunter Sandstones on the south-east, as can be well seen just north of Bridleway Gate Farm near Lee Brockhurst, and at Wixhill near Weston.

Copper ores were formerly worked along approximately north-and-south faults close to Clive Church at Grinshill, also at Yorton Bank, and at Wixhill Hill near Weston.

IGNEOUS INTRUSIONS.

Grinshill and Acton Reynald Dykes.—An igneous dyke, usually only 18 in. in width, has been traced by Mr. Pocock for a distance of two miles from near Holbrook, 2½ miles south of Wem, to the Grinshill Quarries above Acton Reynald. Where it invades the Keuper Sandstone it appears to have ascended along several more or less vertical joints, as four distinct branches have been detected in the hill-side. The dyke is seen again crossing the Upper Mottled Sandstone of the Bunter in a direction 80° east of south in an old lane that leads from the Grinshill road to the quarries. One or other of these branches is probably continuous with one of the dykes at Acton Reynald discovered in 1834 by Murchison,[1] whose observations have been confirmed by information obtained that a dyke passes under the house and tennis-court in a north-westerly direction and forms the side of a well, now built over, in the courtyard. Specimens from this locality have been secured. Murchison mentions another parallel dyke, and also a third, crossing these in an east-north-eastward direction, but no information could be obtained about the two latter.

The rock has been provisionally determined by Dr. H. H. Thomas as an albitised porphyritic basalt, though fresh specimens have since been obtained that may modify this determination.

Dr. Thomas reports that so far as he is aware this dyke is quite unlike any of the others that have been proved to be, or may be, of post-Triassic date.

[1] 'Silurian System,' 1839, p. 295.

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GLACIAL AND RECENT DEPOSITS.

In the Liverpool District mapped by Mr. Wray, numerous borings made in recent years have shown the thickness of the drift to be very variable. Glacial deposits attain their widest development in the south-eastern half of the city.

Along the Mersey shores the boulder-clay forms cliffs 30 ft. high, extending from the Dingle to Otterspool, where it seems to mask a north-and-south hollow in the Triassic rocks.

The Shirdley Hill Sand forms isolated patches preserved in hollows in the boulder-clay. In the neighbourhood of West Derby, where its occurrence has not, it seems, been previously noticed, it attains in places a thickness of over 15 ft. The largest patch occurs around Prince's Park and Otterspool, where it has been dug in comparatively recent times, while it also forms a capping to the adjacent boulder-clay cliffs.

In the south-western part of the Wem Sheet and adjacent margin of the Shrewsbury Sheet, Mr. Wray finds that the Glacial drifts consist of reddish, loamy boulder-clay, with broad spreads of well-bedded gravel and red sand around Stanwardine in the Fields, Baschurch, Broomfields and Montford Bridge. Their thicknesses are extremely variable. Wells and borings have shown them to be 50 ft. thick at Bomere Heath, 100 ft. at Leaton, 96 ft. at Dunn's Heath, and 82 ft. at the Barracks, in the western outskirts of Shrewsbury.

The boulder-clay and the associated gravels consist mainly of slaty Welsh detritus, though granites, apparently of northern origin, and Keuper 'skerry' sandstone, are almost invariably present throughout the district.

Northern erratics appear to be relatively more abundant in the eastern parts of the district. At Leaton, Bicton, Shrewsbury and Preston Montford, the main drift with far-travelled erratics seems to overlie a drift of purely local origin, made up almost entirely of red Triassic sandstone debris.

Shell-fragments are never abundant in the drift, though they have been recorded by Darwin at Shelton Rough, to the immediate west of Shrewsbury, and by Miss Eyton[1] from the now overgrown and disused pits at Merrington Green and Old Wood.

From Ford on the west to Shrewsbury on the east the Severn follows a very meandering course, its total length being nearly 14 miles, while the two localities are only five miles apart. At Ford, in the bed of the river, under a steep bank of boulder-clay, reefs of Lower Mottled Sandstone appear.

The alluvium of the river calls for little comment. It is formed exclusively from the degradation of the drifts and underlying Triassic sandstones. At Ford, Montford Bridge, the Isle, Cross Green, Berwick Park and Gravel Hill, prominent gravel terraces rise 12 to 15 ft. above the level of the recent alluvium.

[1] C. Eyton, 'On the Pleistocene Deposits of North Shropshire,' *Geol. Mag.*, 1870, p. 106.

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These terraces mark an earlier stage in the history of the river. That at Gravel Hill, near Shrewsbury, is intimately connected with an old river-meander, nearly three miles long, which can be traced past Hencott and Ditherington into Shrewsbury. It forms a flat-bottomed and very broad valley, which appears to have been the course of the Severn while the terrace was in process of formation. At a later stage the river cut through the low col between Frankwell and Coton Hill and forsook its former channel, which is now occupied by two insignificant brooks, clearly 'misfits' to the present wide valley. The same process, though not quite so far advanced, is to be seen at the 'Isle,' where a narrow neck, only 350 yds. wide, separates the two ends of a wide meander 4½ miles long.

At the Berth near Baschurch, at Fenemere, and at Eyton, the Glacial sands, which give rise to an undulating and characteristic moundy landscape, are associated with extensive peat-flats.

Farther to the north-east, where surveyed by Mr. Pocock, the high ground extending from Middle to Hawkstone appears to have acted as a barrier to the direct flow of Glacial material from the north-west.

Boulder-clay of a somewhat sandy type occupies most of the low ground south of Grinshill and east of Acton Reynald, the Bunter sandstones appearing only in isolated patches. On the higher ground a few small areas of boulder-clay are found, at Shooter's Hill, near Besford Wood, and around Moston; while the same material covers the ground between Rakepark Lodge and Kenstone, between Weston and Hodnet.

A spread of gravel occurs west of Lee Brockhurst, and sand covers a considerable area round Moreton Corbet. Both these deposits may be connected with an early stage of the River Roden.

4. Cumberland, Westmorland and Furness.

Headquarters: Whitehaven, Cumberland.

B. Smith, M.A., District Geologist.
T. Eastwood, A.R.C.S. } Geologists.
J. Maden, M.Sc. }

Mr. Bernard Smith proceeded to Cumberland early in November to report upon a suitable centre for headquarters, which were finally fixed at Whitehaven. The work of establishing the centre and getting into touch with local interests was then taken in hand. Mr. T. Eastwood, detached from the Midland staff, arrived on December 9th with Mr. J. Maden, whose training in field-work, under the former officer, was commenced on ground that will be some of the first to be mapped systematically in 1921.

Various enquiries as to future prospects in the coalfield north of Maryport and in the iron-ore regions, have been dealt with. Prospecting for hæmatite by boring has been carried on

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extensively during the last few years in the Whitehaven district and as far south as Millom, some of the latest borings being situated at Whitbeck beneath the western shoulder of Black Combe. The search for hæmatite is proceeding in the Vale of Eden also, in an area where abundant fragments of high-grade ore occur in the glacial deposits.

The cores of six borings for iron-ore, three in the Calder Bridge neighbourhood and three near Kirksanton, west of Millom, were examined by Mr. Smith, who discovered grey fossiliferous beds and magnesian limestone in the New Red Series at Kirksanton. More than one boring has been pushed down into fine-grained volcanic rock, riddled with veinlets of calcite, on the assumption that it was Carboniferous Limestone.

Some disturbed and partly-dispersed cores from borings at Hensingham near Whitehaven were examined by Mr. Eastwood.

Detailed records of 14 borings or shaft-sinkings for coal or iron-ore, and abbreviated records of others were obtained. An account of the borings for coal at Bank End and Blue Dial near Maryport, first visited in the early part of the year, and the interesting results obtained, is given in Appendix III., pp. 85–91.

Some of the plans of underground and undersea workings of the Whitehaven Colliery have been transferred to 6-in. Ordnance Sheets.

A series of published 4 miles to 1 in., 1-in. and 6-in. Geological Maps, Vertical and Horizontal Sections, and Survey Memoirs on the district is lodged in the office. These will be available for reference.

Detailed descriptions of the lead and zinc mines of the Lake District, examined by Mr. Eastwood, to form one of the Special Reports on Mineral Resources, are being prepared for publication.

5. Northumberland and Durham.

Headquarters: Newcastle-on-Tyne.

R. G. Carruthers, District Geologist.
C. H. Dinham, B.A.
G. A. Burnett, B.Sc.
F. Marsden, B.Sc.
A. Fowler, M.A., B.Sc., A.I.C.
} Geologists.

The new unit allotted to the North-Eastern coalfield began operations towards the close of the year. It was decided that, in the first place, special attention should be paid to the 'Limestone Coals,' as they are the main reserve in this part of England. There is much doubt over the finer points of correlations and structure amongst these rocks, and a revision of the existing maps is certainly called for. Messrs. Burnett and Marsden have begun work in the Scremerston field, south of Berwick, and have completed the preliminary measurements of

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the typical coast-section, in which they have been assisted by Mr. Fowler.

6. Borings for Oil in Derbyshire and Staffordshire.

The progress at the Petroleum Department's borings for oil in Derbyshire and Staffordshire has been carefully followed; Mr. Bromehead has collected geological information from the seven borings in Derbyshire, Mr. Eastwood from those in Staffordshire; several visits have been paid to the sites and many samples examined in the Survey Office. The following table shows the progress from the beginning of 1920 to the time of going to press, May 1921.

Well.	Depth in January 1920.	Depth in May 1921.	Remarks.
	Ft.	Ft.	
Ridgeway -	2,996	2,996	Abandoned January 1920.
Renishaw -	3,645	4,200	Carboniferous Limestone at 4,100 ft.
Brimington -	2,660	4,040	Carboniferous Limestone at 3,000 ft.
Heath - -	2,955	4,009	Carboniferous Limestone at 3,950 ft.
Hardstoft -	3,112	3,112	No change.
Ironville II -	3,570	4,005	Now abandoned.
Ironville I -	2,580	3,655	Still in Carboniferous Limestone.
Werrington -	1,920	—	Fishing.
Apedale I -	1,350	1,350	Abandoned.
Apedale II -	—	3,450	Started September 1920.

From the economic point of view the results have been disappointing. Hardstoft continues to yield about 1 ton of oil per day by natural flow, but elsewhere only traces of oil have been found. At Heath, the nearest to Hardstoft of the other borings, a few ounces of highly filtered oil were met with at the junction of the Limestone Shales and Carboniferous Limestone at 3,950 ft.; slight indications were also found at Ironville II and Ironville I, notably in the latter at 3,630 ft. This 'show' and that at Heath were torpedoed, but no further yield resulted. The top of the Limestone showed no trace of oil at either Brimington or Renishaw, and there is no reason to modify the remarks on the origin and accumulation of the oil made in the 'Summary of Progress for 1919' (pp. 22, 23).

From the purely geological point of view, it will be seen that all the Derbyshire wells have now reached the Carboniferous Limestone; at Ironville I, 1,600 ft. of that formation has been bored through, without reaching the base. Igneous rocks have been encountered in several of the borings; at Brimington, 850 ft. of lavas, with a few thin intercalations of limestone, have

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already been proved. As was expected, both the Lower Coal Measures and Millstone Grits show a steady increase in thickness from south to north.

In Staffordshire, Apedale No. II well was started a few yards distant from No. I well, which was abandoned, the horizon being just above the Bullhurst Coal. At November 9, 1920, the depth was 1,060 ft. in Coal Measures, and the rocks penetrated were sandstones, shales and several coals. At about 1,465 ft. red and green ashy material was entered, approximately at the top of the Millstone Grit, and this continued to a depth of 3,450 ft. (March 23, 1921). This great thickness of volcanic strata was not expected in the bore, as no similar rocks are known to occur near this horizon except at Astbury (Staffordshire) and Ashover in Derbyshire, where they are comparatively thin.

(B)—SCOTLAND.

The field-work in the Highlands has been proceeding in two districts :—

1. West Highland District under Mr. E. B. Bailey, M.C., B.A.
2. North Highland District under Mr. M. Macgregor, M.A., B.Sc.

The coalfield revision was carried on in two districts :—

3. In North Ayrshire under Mr. E. B. Bailey. M.C., B.A.
4. Stirlingshire and Clackmannanshire District, and part of Lanarkshire (Douglas Coalfield), under Mr. M. Macgregor, M.A., B.Sc.

1. West Highland District.

E. B. Bailey, M.C., B.A., District Geologist.
E. M. Anderson, M.A., B.Sc.
J. E. Richey, M.C., B.A.I.
G. V. Wilson, B.Sc.
G. A. Burnett, B.Sc.
} Geologists.

The area surveyed lies mainly in Mull and adjacent islands including Staffa and Iona, Sheets 43 and 51 of the 1-in. Map of Scotland. A commencement has also been made in Ardnamurchan, Sheet 52.

PRE-MESOZOIC ROCKS.

Iona.—The presence in Iona of Lewisian Gneiss, with associated marble, and of sediments strongly recalling the Lower Torridonian of Skye has long been known, and their distribution has been roughly indicated by Sir Archibald Geikie in his 'Geological Map of Scotland' 1892. Mr. E. M. Anderson adds a new locality for the sediments of Torridonian type, for besides forming a strip along the eastern side of the island, they

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compose Eilean Chalbha and the neighbouring foreshore of the north-western coast.

Undoubted altered sediments within the Archæan complex occur (1) in the neighbourhood of the marble quarry, near the most southerly point of Iona, and (2) to the north of Dun Cul Bhuirg, on the western coast. The quarried marble is an almost vertical band about 20 ft. in thickness, pure white in colour, or white with characteristic greenish streaking. It is associated with other certainly sedimentary material, including a dark graphitic rock, which must be an altered shale.

The sediments to the north of Dun Cul Bhuirg also include bands of marble, one of which has been worked to a very small extent for ornamental purposes, under the name of the 'Silverstone.' It is a pinkish marble, variegated by grains of green serpentinous material, and 'silvery' from the presence of pale-coloured mica, no doubt magnesian. There is also at this locality a broad band of brown biotite-gneiss, very massive and unbanded in its weathered appearance. This passes into a graphite-schist, which is in part pyritous, and is strongly reminiscent of a type found elsewhere in Scottish Archæan sediments.

A period of intrusive activity followed the deposition of these sediments, as is shown by the presence among them of very fine hornblende-schists or epidiorites. They are also cut by coarse unfoliated bands of pegmatite of a type already noted by Mr. Craig in the adjacent island of Soa.[1] As pegmatites are almost entirely absent from the neighbouring sediments of Torridonian facies, their occurrences in the cases just referred to would seem to belong to a late phase of igneous activity of Archæan age, a phase which it is to be noted was later than any period of metamorphism and shearing movements.

Unfoliated pegmatites are everywhere the latest intrusions of the Lewisian complex of Iona, and are by no means confined to areas of undoubted sediments. The basis of the igneous gneiss consists in large part (1) of banded granitic rocks, sometimes containing a certain amount of hornblende in their darker laminæ, and (2) of massive hornblende-gneisses, much coarser in grain than the hornblende-schists already mentioned. The whole formation throughout the island is much veined and irregularly intergrown with epidote. A local concentration of magnetite will be noted on p. 43.

The supposed Torridonian series of the eastern strip in Iona may be roughly divided as follows :—

(2) A younger flaggy group characterised by rapid alternations of more siliceous and more shaly material.

(1) An older group of grits and conglomerates with subordinate shale.

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[1] E. H. Cunningham Craig, 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull' (*Mem. Geol. Surv.*), 1911, p. 79.

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A coarse conglomerate can be seen at certain points along the old gneiss margin. The commonest constituents are fragments of granitic rocks evidently derived from the gneiss, and of any size up to two or three feet in length. Boulders of hornblendic rock and of quartz are also occasionally present, as, for instance, at the dividing line of the two formations at the most northerly point on the island. The conglomerate is interbedded with and overlain by pebbly grits, in which the small pebbles consist of quartz and felspar, while the matrix, like that of the conglomerate, is dark grey or dark green in colour. Less commonly, the base is more yellowish green, suggesting epidote. The part of this formation next to the gneiss shows signs of rather intense crushing, perhaps because it acted as a zone of weakness during some period of stress. There is, however, so far as has been observed, no definite break or thrust along the margin. It is important to realise that the crushing referred to above does not introduce uncertainty in the interpretation of the conglomerates. A visit to the wave-washed exposures at the Pigeon's Cave on the south coast is enough to settle this point. There conglomerate layers are interbedded with grits and shaly layers, and one notes that the included fragments differ markedly in character from their surrounding matrix. The crushing manifests itself in the disruption of the bedded series, it does not produce anything approaching a crush-conglomerate.

The later portion of the grits is interbedded with bands of shale, some greenish, others dark and probably carbonaceous, while there is a broad band of dark shale intervening between the last of the grits and the succeeding flags.

The sediments of the north-western coast and Eilean Chalbha are somewhat puzzling in character, but may very possibly represent some part of the conglomeratic group (1) of the east.

The puckering and cleavage which have affected the similar rocks of Colonsay and Islay are almost absent in Iona. Apart from the movement near the margin of the gneiss, these sediments show little sign of dynamic metamorphism. Their bedding is, however, everywhere steeply inclined, E.S.E. in the eastern outcrop, and south-east in the north-western.

The Ross of Mull Granite must underlie a considerable part of the Sound of Iona, as since Macculloch's day it has been known that three small islets close to the Iona shore are composed of granite of the Ross type. It is interesting to note that the band of shale between the grits and the flagstone group has a spotted appearance where it comes near these islets, but not elsewhere. This alteration would seem to prove the post-Torridonian age of the granite, which has hitherto been somewhat in doubt. To avoid confusion, it should be added that Macculloch speaks of an 'appearance of transition' into the granite, but was probably misled by the presence of felspar grains in the flagstone series and also among the grits.

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The unfoliated post-Torridonian intrusions of Iona belong to two classes :—

(1) Basic dykes (apparently basalt and camptonite) run in every azimuth between N. 30° W. and due east and west. Some at least of this group are probably Tertiary, and so do not come under the heading of this section.

(2) The second class includes lamprophyres, which are somewhat irregular but show a marked tendency to follow a series of north and south joint-planes, which dip westwards throughout the island at angles of about 30°. It also includes a group of more acid intrusions, usually pink in colour, and sometimes with basic margins. These occasionally follow the joint-planes referred to, but more often are irregularly rolling with a tendency to horizontality. It is possible that the whole of this class of intrusions are of the same period as a set of mica-traps, granite-porphyries, and porphyrites, found by Messrs. Craig and Bosworth,[1] to cut the Ross of Mull Granite while themselves cut by certain north-westerly dykes. Further evidence of the age of the Ross intrusions will be given presently in the description of Gribun.

Gribun.—Iona has been interpreted by Mr. C. T. Clough[2] as probably a part of the foreland of the Moine Thrust. The thrust itself may be hidden in the Sound of Iona or obliterated by the Ross of Mull Granite; at any rate the well-known gneiss of Erisgeir, Inch Kenneth, and Gribun, with the fuller succession of the Ross, almost certainly belong to the Moine series.

Mr. E. B. Bailey and Mr. G. A. Burnett have found the gneiss just mentioned to be remarkable for its pebbly character. It is a false-bedded arkose-gneiss, retaining much of its sedimentary aspect despite a somewhat high crystallization with a development of garnets in certain micaceous partings.

Two steep sheets of coarse mica-trap have been found by Mr. Bailey on the shore N.W. of Balmeanach traversing the Gribun gneiss and themselves cut off by the unconformable Trias. They dip N.W. and almost certainly belong to the same series as the numerous mica-trap sheets recorded by Mr. Bosworth in 1909 as cutting the Ross of Mull Granite. Thus additional indirect evidence is afforded for Judd's generally accepted view that the Ross Granite is of pre-Mesozoic age.

MESOZOIC ROCKS.

Gribun and Inch Kenneth.—Prof. Judd's classic description supplies the natural datum from which to reckon further advance.

[1] E. H. Cunningham Craig, 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull' (*Mem. Geol. Surv.*), 1911, p. 86.
T. O. Bosworth, 'Summary of Progress for 1909.' (*Mem. Geol. Surv.*), 1910, p. 27.

[2] C. T. Clough in 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull.' (*Mem. Geol. Surv.*), 1911, p. 77.

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Prof. Judd[1] recognised Poikilitic, Upper Greensand (Cenomanian), and silicified Chalk. Some years later Mr. J. S. Gardner[2] discovered Lower Lias in the much landslipped Wilderness (north and south of Aird na h-Iolaire), and corrected Judd's mistaken impression that Greensand is to be found in Inch Kenneth. In addition, Gardner questioned whether Judd's 'Chalk' was *in situ*, for he thought it all *remanié* in Tertiary deposits, but in this he went too far, as may be seen for instance in Allt na Teangaidh, just below the main road.

The results of last year's work may now be briefly stated. The various groups were mapped by Mr. Bailey, the main exposures were measured by Mr. W. Manson, who collected 750 fossils, and the examination of these has been started by Dr. G. W. Lee.

Judd's Poikilitic—or Trias, as one is justified in calling it—is some 200 ft. thick at Inch Kenneth, where the gneiss floor disappears below the sea, and about 10 ft. thick 2½ miles farther south where gneiss rises 700 ft. in the coastal cliffs of Mull. An unrecorded feature is the abundance of pebbles of red Torridon arkose and fine grained (? Durness) limestone. Some of these far-travelled limestone pebbles are enclosed in an envelope of chert.

For about 2½ miles along its outcrop the Trias is succeeded by definite Rhaetic. The prevalent type is dark sandy limestone, or calcareous sandstone, with rather wavy bedding and no trace of concretionary structure. Lamellibranchs are numerous. The best section is in Allt na Teangaidh near Balmeanach, where about 30 ft. are laid bare. The fossils include *Pteria contorta* [*Avicula*], *Gervillia præcursor*, and *Pecten valoniensis*. This is the second record from Scotland of demonstrable Rhaetic beds—the only occurrence known hitherto is the mass of shale found by Messrs. Peach and Gunn tumbled down the throat of a Tertiary volcano in Arran.

In the Wilderness the Trias is succeeded in a low cliff south of Uamh nan Calman by shales and cement-stones. Although the section suggests continuous deposit there is nothing of the type of the Balmeanach Rhaetic—no fossils could be found, but the facies of the shales and argillaceous limestones is distinctly Liassic. What follows is confused by landslipping, but in small cliffs south of Aird na h-Iolaire the lower part of the Hettangian is very definitely represented, and in associated loose blocks one finds a Sinemurian fauna. Taken together these correspond with the Broadford Beds of Skye.

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[1] J. W. Judd, 'The Secondary Rocks of Scotland.' *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, pp. 694, 732. See also a critical discussion of the unconformity at the base of the Gribun Secondaries, J. Macculloch, 'Western Islands of Scotland,' vol. i, 1819, p. 563.

[2] J. S. Gardner, 'Leaf Beds and Gravels of Ardtun, Carsaig, etc. in Mull.' *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, p. 284.

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The Hettangian of the cliff section is divisible into two :—

(*a*) One ft. red mudstone, overlain by 19 ft. mostly micaceous calcareous sandstone, 8 ft. sandy limestone and calcareous shale crowded with *Ostrea liassica*, overlain by

(*b*) Twenty ft. shales and limestone assignable to the Planorbis Zone.

The Oyster Bed facies, characterising the upper part of (*a*), is well known in the lower Hettangian of England and again in Skye, but not elsewhere in Mull. The *planorbis* fauna of the lower Hettangian has never hitherto been forthcoming in Scotland, though carefully searched for.

The Sinemurian fauna has been found, as already stated, in loose blocks. One may mention *Lima gigantea* indicating the lower part of the Sinemurian, and typical *Gryphaea arcuata*, also betokening Sinemurian but not necessarily its lower stages.

Prof. Judd, the original discoverer of Cretaceous rocks in Scotland, emphasized the bearing of his observations upon Suess's generalisation regarding the Upper Cretaceous transgression of the European area (*op. cit.*, p. 683). For instance, in the Gribun peninsula nothing remains between the Lower Lias and the Cenomanian.

Dr. G. W. Lee, some years ago, justified Judd's employment of the name Cenomanian for the Greensand of Mull by finding a zonal ammonite near Loch Don. The best Gribun exposure is below the road in a great landslip N.E. of Balmeanach. Oyster banks with *Exogyra conica* and occasional *Serpula* are very conspicuous. Additional fossils to those recorded by Judd are : *Pecten orbicularis* and *Pecten asper* (?). Judd's *Spongia paradoxica* is probably based on highly characteristic sandcasts, and Mr. Bailey points out that these resemble forms common in the Upper Greensand of Eastbourne for which Mr. Clement Reid[1] has offered a very different interpretation.

The Greensand of Gribun may be taken as about 20 ft. thick. Above follow white sandstone 10 ft. and Chalk 10 ft. The white sandstone has not previously been described from Gribun, but it is in keeping with Judd's general sequence.

Ardnamurchan.—Mr. J. E. Richey commenced the examination of the Ardnamurchan Secondaries. In the cliff west of Sron Bheag, the southernmost point west of Kilchoan, there is a mass of baked sedimentary rock which is probably Inferior Oolite. It is about fifty feet thick and has a distinct resemblance to Chalk; the exposure is rather inaccessible and has not yet been fully examined.

TERTIARY SEDIMENTS IN MULL.

Mr. Bailey has found that the silicified chalk of Gribun is veined by sandstone, and that in places (*e.g.*, Allt na Teangaidh) similar sandstone constitutes a thin overlying bed. This sandstone shows marked wind-rounding of its grains, and may, there-

[1] Clement Reid, 'The Geology of Eastbourne.' (*Mem. Geol. Surv.*), 1898, p. 5.

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fore, be claimed as a desert deposit. Another interesting point is that the silicification of the chalk is of later date than the desert sand. An extension of the chert which replaces the chalk in many cases serves as matrix to the grains of sand. Elsewhere it is commonly found that the grains have added fresh crystal facets, and thus lost much of their rounded outline.

To investigate the extent of this Tertiary desert sand, a visit was made to the Tertiary sandstone of Carsaig. Wind-rounding was here again very evident, and included fragments of silicified chalk were seen surrounded by a halo of chert serving as a local matrix for the adjacent sand-grains.

In Allt na Teangaidh the desert sand is overlain by the thin, red mudstone so often met with at the base of the Mull lavas. This deposit, and the somewhat later leaf-beds and coal-seams, obviously indicate a change of climate.

TERTIARY LAVAS.

Local discordance, Bloody Bay, Tobermory.—A general feature of the Mull lavas is the even way in which they follow a thin layer of Tertiary sediments which in turn rests with misleading conformity on underlying Mesozoic rocks. Mr. G. V. Wilson has found a most unusual appearance presented in an old sandstone quarry in the sea cliff of Bloody Bay. The locality is about 1¼ miles S.E. of Ardmore Farm and of easy access from above, or by boat from Tobermory. Prof. Judd, speaking of the sandstone, justly remarks: "the eroded surfaces of these beds is seen to be directly covered by the . . . basaltic lavas" (*op. cit.*, p. 715). The most interesting feature of the exposure is the peculiar way in which the flat-bedded sandstone juts up as a knob into the overlying lavas (Fig. 1). Along

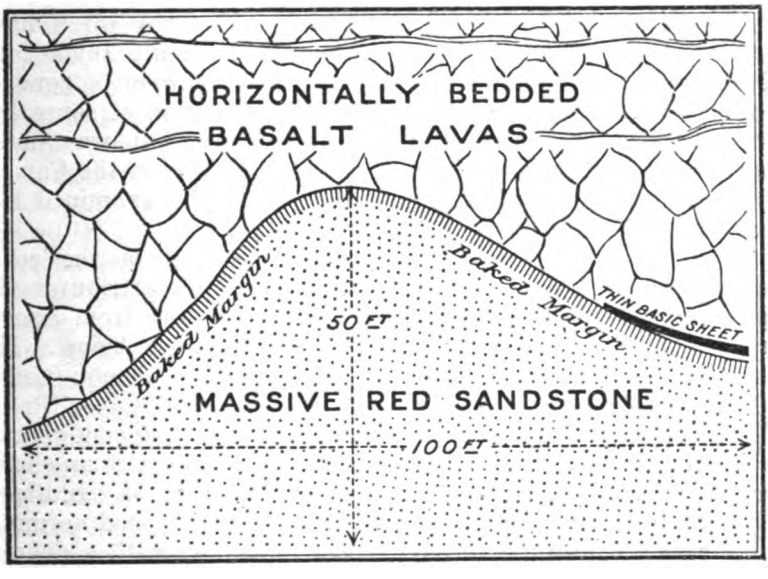

FIG. 1.—Tertiary lavas overlying a weathered knob of sandstone at Bloody Bay.

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the line of contact the sandstone shows a baked zone which extends inwards for several inches.

The sandstone is of good quality and has been used in the wall of the path leading to Rudha nan Gall Lighthouse. It is at least 50 ft. thick, current-bedded and red in colour, with a small proportion of rounded grains. It also carries irregular concretionary bands of iron-ore. The outcrop can be traced for about 200 yds. and is terminated in both directions by what appears to be a fault running almost parallel with the cliffs and bringing basalt lavas down to sea-level. The age of the sandstone remains doubtful.

Columnar Lavas, Staffa and elsewhere.—The cliffs of Gribun have enabled Mr. Bailey to realise that the columnar lavas there seen all occupy a very low position in the Plateau Lava group of Mull. Comparison with other districts is rendered somewhat unsatisfactory, as columnar structure is often poorly displayed in ordinary inland exposures, but it seems certain that all the columnar lavas of Mull are of relatively early date. They have a geographical as well as a time limit. They reach their fullest development where mapped by Mr. Anderson in the cliffs west of Carsaig, whence they continue by Ardtun into the Gribun peninsula, Ulva and Staffa. Reidh Eilean, outside Iona, has yielded Mr. Anderson a hitherto unrecorded occurrence of columnar structure of spectacular type, but the columnar rock in this case is of unusually doleritic texture, and its field relations are hidden by the sea. The only columnar lava not falling within the south-west corner of the Mull district is an example noted by Mr. Wilson towards the base of the series at Bloody Bay, near Tobermory.

A feature of a large proportion of the columnar lavas of the Mull area is their triple-zoned appearance. They often have a thick slaggy top merging down into an equally thick zone of narrow wavy columns, which rests in turn upon a zone of more massive vertical columns. This combination of zones has received little attention in previous writings, but was noted some years ago by Mr. Anderson and Mr. Wilson in the Carsaig cliffs. It is nowhere better seen than in Staffa, examined last year by Mr. G. A. Burnett.

Prof. Iddings gives a very useful discussion of the zonal jointing of analogous American examples, and attributes the upper zone of columns to irregular rapid cooling from above, and the lower zone to regular slow-cooling from below. His interpretation accounts for a very striking phenomenon visible on the foreshore a little north of the Clamshell Cave, Staffa. Here the two systems of joints, instead of becoming confluent at their contact, as is often the case, seem to be mutually repellant, for they suddenly swing into parallelism. Prof. Iddings'[1] explanation is that the jointing tends to be propagated normally to a retreating isothermal surface corresponding with a definite

[1] J. P. Iddings, 'Igneous Rocks,' vol. i, 1909, figs. 13, 15, 16, p. 322.

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temperature, and that when cooling from above and below brings two such surfaces together the form of the combined surfaces is materially modified by a rounding off of the angle of contact—from which follows a corresponding deflection of the developing joint-planes. On the other hand, the commonly observed confluence of the two sets of joints is, of course, to be interpreted as evidence of the influence which two approaching joint systems may exercise upon one another, and is not to be taken as a contradiction of Prof. Iddings' explanation.

The two columnar zones of the Fingal's Cave lava of Staffa are among the most familiar of geological phenomena, though they have been previously ascribed to independent flows in Sir A. Geikie's descriptions. Mr. Burnett has shown their true relationship. He has also found that the northern half of the traverse between Clamshell Cave and Goat Cave affords an excellent coast section of the top zone of the Fingal's Cave lava consisting of commingled slag and solid, merging finally to pure slag. In the mixed part of this uppermost zone early masses of slag have clearly been involved in, and carried forward by, still liquid portions of the flow, the latter now represented by columnar basalt. At Goat Cave the slaggy top of the Fingal's Cave lava is covered by a few feet of carbonaceous and ashy sediment, which in turn is overlain by further basaltic flows constituting Meall an Fulann.

It has long been known that the Fingal's Cave lava is underlain by red ash. A convenient exposure can be reached from above at Port an Fhasgaidh. The massive columns here reach down to about a foot from the ash, but the bottom layer of the lava is brecciated and vesicular. A 1-ft. sill of basalt, chilled at top and bottom and clearly transgressive, lies just a little below the lava base.

The Fossil Tree of Burgh.—Another famous columnar lava of the district is that which flowed round and over the fossil tree of Burgh—to use a now familiar name. The cast of this tree trunk stands in a recess of the coastal cliff of the Gribun peninsula, 150 yds. north of the waterfall of Allt Airidh nan Caisteal. Geologically speaking it is the most wonderful spectacle in all Mull, and like so much else of interest in the west of Scotland, was made known over 100 years ago by Macculloch. Sir Archibald Geikie has published a photograph in his Text Book of Geology (1903, p. 758). The cast of the tree is seen in vertical section, and looks like a pipe, nearly 5 ft. broad and about 40 ft. high, and largely filled with breccia consisting of lumps of 'white trap' and charred wood. The lower part of the pipe encloses a partially silicified semi-cylinder of wood glittering with quartz crystals. The diameter of the cylinder is about 3 ft., and outside is a hollow where soft black coniferous wood, a couple of inches thick, may be dug out with a hammer. In Macculloch's day the wood continued as a coat around the silicified cylinder, but since then has been ruthlessly stripped away by curio-hunters.

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The pipe rises in the heart of a columnar basalt, and the columns as they approach it turn so as to meet it everywhere at right angles. Geikie and Gardner have described the pipe as reaching right up through one lava and overlain by another, but such is not the case. Macculloch seems to have thought that the tree had somehow found its way into a fissure of the basalt.

A prostrate tree is included in a brecciated portion of the same lava exposed in a cave 230 yds. north of the upstanding tree. It is probable, Mr. Bailey says, that these two trees are mere remnants of a forest. At any rate the lower part of the lava in this neighbourhood has very unusual characteristics. It rests regularly on a thin carbonaceous layer following an important ash, but within itself it is wonderfully irregular. It consists, in fact, of a chaotic assemblage of columnar and more or less brecciated vesicular basalt. The columnar basalt traverses the brecciated, or sweeps round great masses of it 40 or 50 ft. high. Everywhere the columns are at right angles to the line of contact, no doubt because the slaggy breccia could offer practically no resistance to contractional force during cooling. The columnar basalt sometimes comes in contact with the underlying carbonaceous mud, and is distinctly chilled, as has been found to be the case with a few other lava bases in Mull; but it is unchilled where it joins the breccia.

The lava is unusually thick, and the irregularity of its basal part may be looked upon as a special feature. Apart from this it exhibits the triple zoning already mentioned as characteristic of the Fingal's Cave lava, etc.

Flow-Banding and Pipe Amygdales.—A curious type of flow-banded lava has been met with in many parts of the district surveyed last year, more particularly in Gometra mapped by Mr. Burnett; the banding is often sufficiently lenticular to remind one of pillow structure, but the lenticles are, on the whole, much too elongated to be called pillows, and they are not defined by noticeably chilled margins. Each band has typically three layers, a basal zone with pipe-amygdales, a middle solid zone, an upper zone with crowded little rounded amygdales. There is a distinct separation of the bands, for nowhere can one point to round vesicles of the top of one band extending up among the pipes of the next. Mr. Richey has found a section at the roadside 350 yds. E. of Kilninian Church, which throws considerable light upon the conditions attending the formation of this banding. Reddening such as is commonly attributed to surface weathering during the volcanic period, extends along the junction lines of the successive bands; this seems to point conclusively to an imperfect contact of the bands, so that it is fair to regard the banding as a surface phenomenon resulting from successive overflows upon the surface of a parent lava.

Pegmatitic Veins.—Several examples of contemporaneous pegmatitic linings to vesicles, and of associated veins, have been encountered this year in basaltic lava flows. Mr. Bailey had

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previously noted the phenomenon on the shores of the sound of Mull, and Dr. McLintock[1] has described it from the Ben More district. The interest of the recent finds is their occurrence outside the area of pneumatolysis of central and eastern Mull. The pegmatitic veins, where, for instance, they have been found by Mr. Burnett in Gometra, are seen stringing basalt lavas which still carry their olivine in large measure unaltered.

Ben More Mugearite.—Sir A. Geikie,[2] in separating a pale group of Mull lavas forming the upper portion of Ben More, spoke of the occurrence among them of trachytic flows. During the survey of the district it was thought that Geikie's trachytic flows were really a great mugearite sill, and this statement has been published. On the other hand, Mr. Wilson, in the Loch Buie district, definitely recognised as lavas certain mugearites which evidently occupied much the same stratigraphical position as the mugearite of Ben More. Accordingly, Mr. Bailey investigated the matter last season, and states that the continuation of the Ben More mugearite south of Kinlochscridain can be shown to be a lava with a weathered, slaggy top. In keeping with this, Mr. Richey has found a thin sedimentary layer, immediately above the mugearite in Ben More itself, containing numerous fragments of mugearitic type. Moreover, the section which led to the view that the mugearite was intrusive, when examined this year by Mr. Bailey and Mr. Anderson, proved to be misleading.

TERTIARY INTRUSIONS.

Mull Sills.—Messrs. Bailey and Anderson have completed the mapping of the Loch Scridain area of sill-intrusion, and Mr. Wilson has found and mapped a distinct area in the northern end of the island. In both cases the sills are very transgressive.

Among the noteworthy features of the Loch Scridain sills are :—

(1) frequent residuum of pitchstone,
(2) numberless highly altered xenoliths,
(3) occasional and local absence of chilled margins.

(1) and (2) of the above have often been described already. Mr. Bailey has now found instances combining all three characteristics, as, for instance, at Scobull Point, Loch Scridain. Messrs. Anderson and Radley[3] have pointed to the pitchstone residuum as evidence of retarded crystallization, and have argued that it has been determined by an unusually high water-content in the magma supplying the sills. Mr. Bailey points

[1] W. F. P. McLintock, 'On the Zeolites and Associated Minerals from the Tertiary lavas around Ben More, Mull.' *Trans. Roy. Soc. Edin.*, vol. li, 1917, pp. 15, 18, 21.

[2] A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. ii, 1897, p. 214.

[3] E. M. Anderson and E. G. Radley, 'The Pitchstones of Mull and their Genesis.' *Quart. Journ. Geol. Soc.*, vol. lxxi, 1915, p. 205.

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out that the characteristics (2) and (3) suggest retarded consolidation in contact with cold surfaces, not by any means the same phenomenon as retarded crystallization, but very likely attributable to the same cause.

Mull Dykes.—The belt of N.W. dykes belonging to Mull is about 10 miles broad. Mr. Wilson has found that the topography of northern Mull, within the belt, is lineated N.W. and S.E., in striking contrast to that of adjacent districts.

Ardnamurchan Complex.—In a preliminary investigation of the Ardnamurchan peninsula, Mr. Richey has confirmed Dr. Harker's[1] announcement of a well-defined belt of centrally inclined basic sheets (cone-sheets). The sheets dip to a common centre, which is situated approximately beneath Beinn na h-Imeilte, between Sanna Bay and Kilchoan. The belt can be traced round half the circumference of a circle, extending from Faskadale on the north side of the peninsula to the south-west side of An Acairseid. It is at any rate three miles in annular width. The sheets composing the outer half of the belt are individually the more massive, and attain unique development on Ben Hiant,[2] where single members are upwards of 100 ft. thick. The dip also varies, becoming gentler towards the exterior of the belt, as, for example, in the Ben Hiant district.

The great gabbro mass, long known to form the western part of the peninsula, has a steep or vertical junction, which follows closely the strike of the belt of cone-sheets. It is considered to be later than the sheets for the following reasons :—

(1) The gabbro is free from the sheets, whereas the sheets occur in great force immediately outside it.

(2) The sheets, together with their country rock, become increasingly altered by thermal metamorphism towards the gabbro junction.

(3) An isolated area of basalt lava traversed by sheets, presumably belonging to the set of cone-sheets, was observed surrounded by gabbro on Meall an Tarmachain.

PREGLACIAL MARINE EROSION.

The district includes many evidences of Preglacial marine erosion at about 100 ft. above sea level, already described by Mr. Wright,[3] whose conclusions have been confirmed. Of cognate interest is an old sea cave at a higher level, to which Mr. Burnett's attention was directed by Mrs. Clark of Ulva. It opens on the south-east slope of A'Chrannag, Ulva, and its floor, where reached in a trench, lay 150 ft. above high-water mark. It measures

[1] A. Harker, 'Anniversary Address of the President.' *Quart. Journ. Geol. Soc.*, vol. lxxiii, 1917, part 1, p. xciv.

[2] A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. ii, 1897, pp. 318-322.

[3] W. B. Wright, 'Preglacial Shoreline in the Western Isles of Scotland.' *Geol. Mag.*, 1911, p. 97.

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40 ft. broad, 50 ft. deep, 25 ft. high, and its bottom is covered with a deposit of boulder-clay up to 5 ft. thick, charged with granite, gneiss, and Liassic limestone derived from Morvern and the Sound of Mull. The far-travelled erratics are, taken together, much more numerous than basalts such as might have come from the island itself. The level corresponds with that of a well-marked, though heavily glaciated, shoreline found some years ago by Mr. Anderson at the head of Loch Scridain.

ECONOMICS.

Iron Ore, Iona.—Magnetic iron ore was known to have been found near the southern end of Iona. Mr. E. M. Anderson reports its occurrence at two localities :—

(*a*) Close to the shore directly north of the eastern end of Eilean Musimul. The material here forms a vertical band from 2 ft. to 4 ft. in width, traceable for about 200 ft., and running parallel to the banding of the adjoining gneiss. The magnetite is mixed with garnet and other impurities, but the state of concentration is, perhaps, rather greater than that of the next locality.

(*b*) Close to the shore just west of Port an Fhir-bhreige (the western part of St. Columba's Bay). There is here a zone of impregnation some 10 or 15 yards in width, which can be traced for nearly 100 yards; but the deposit is most irregular, and only a small part of this thickness can be classed as even inferior ore.

Until assays of the material have been made, it is not possible to estimate the amount of iron, and it is likely that the limited nature of the deposits so far apparent would prevent them from being profitably workable.

Marble, Iona.—The well-known Iona marble quarry has not resumed working since the war. The stone was used for interior decoration, especially in churches. The available reserves are not sufficient to allow the development of the industry on a large scale, but would probably meet a limited demand for many years to come.

Sandstone, Bloody Bay, Mull.—Attention may be directed to the sandstone of Bloody Bay, described on p. 38. It has already been quarried for the Rudha nan Gall lighthouse, and is a serviceable stone on the water's brink should building material be again required in this locality.

Lime, Mull.—The white sands of Calgary Bay could supply an inexhaustible supply of lime. Mr. Wilson reports rather more than 70 per cent. of $CaCO_3$ in a type sample.

The cornstones at the entrance of Loch na Keal might perhaps be used for local purposes. The most favourable outcrop is that of the sea-cliff below Inch Kenneth Chapel.

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2. North Highland District.

M. Macgregor, M.A., B.Sc., District Geologist.
C. H. Dinham, B.A.
H. H. Read, B.Sc., A.R.C.S. } Geologists.
D. Haldane

Field-work was resumed during the past season in the North Highland District, and considerable progress made with the survey of One-inch Sheet 102. The ground surveyed lies in the south-eastern quarter of the sheet, partly in Sutherland, partly in Easter Ross.

Easter Ross.

In the Ross-shire ground, Mr. Dinham surveyed an area lying north of the lower part of Strath Carron. The greater part of this tract is covered by morainic drift, and the rocks, which are found only in the stream sections and along the shores of the Kyle of Sutherland, consist of the usual siliceous granulites of Moine type, with thin and rare pelitic bands, scarce sills of chloritic and garnetiferous hornblende-schist, and lamprophyres of two types, distinguished by brown and brick-red weathering. Near Culrain, where the Kyle first narrows, the top of Lamentation Hill (Creag a' Choineachan) and the ground to the west of it are comparatively free from drift. At the very summit of this hill outcrops a brown-weathering lamprophyre, with abundant well-rounded inclusions of schist and of a pink granite. The contrast between the resistance of this tough, scarcely jointed rock to the action of ice, indicated by its tendency to occur in rock knobs, and its easy susceptibility to ordinary atmospheric weathering, is well illustrated here. This dyke has been traced at intervals for at least 1,000 yds. to the W.N.W.; in the opposite direction it is probably continuous, though the connection is not visible, with the exactly similar dyke of Sithean Mor across the Kyle (p. 47).

The 50-ft. Raised Beach forms a well-marked flat here and there on the west shore of the Kyle. At the lower end of Strath Carron the sands and gravels of this beach must have constituted a delta, the greater part of which was situated below the level of tidal waters, while the higher layers, and the part which lay furthest upstream, were fresh-water deposits at the mouth of the Carron; similarly with the present-day river, the delta, formed partly at the expense of the earlier one, lies on the average two or three feet above high-water mark, and the tides do not penetrate more than a quarter of a mile upstream from the river mouth, so that the highest layers of the delta are properly fresh-water deposits. The 50-ft. beach rises to 62 ft. about a third of a mile east of the railway, but beyond this point the surface becomes broken and the beach merges into a tract of irregular gravel mounds, separated by hollows without outlet, indicating the proximity of the tongue of a valley glacier.

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South of the viaduct across the Kyle at Culrain the 50-ft. beach must have been chiefly formed out of materials brought by marginal and other streams, and deposited here at the foot of the Oykell Valley glacier. The fluvioglacial origin is also indicated by the presence of two or three kettle-holes, close to Culrain Station, in the otherwise flat-topped beach. Before the sea sank below the 50-ft. level, the ice had retreated at least as far as Inveran, for the raised beach, though mostly forming a narrow fringe with broader expanses near Inverhouse, still makes a well-defined flat, with a large kettle-hole near the sharp bend of the road east of Rheantaoir. West of this, however, the terrace breaks up into hollows and mounds, the latter not rising higher than the level of the beach until beyond Rhelonie, where all trace of the terrace feature finally disappears.

There is some indication of a glacial overflow channel which, entering the wood south of Rheantaoir just below the 100-ft. contour, utilised and partly deepened the gorge leading eastwards to Inverhouse. The broad spread of 50-ft. beach at this point, already referred to, may be largely formed out of materials brought through this channel into tidal waters, at a time when the ice-foot lay between Inveran and Rheantaoir.

SUTHERLAND.

Messrs. Read and Haldane report that in the ground surveyed by them between the Kyle of Sutherland and Strath Fleet, the country rock consists of siliceous granulites in which occur granite masses and subordinate igneous rocks of various kinds.

Schists.—In type, the Moine rocks are very uniform throughout; they are white or pinkish siliceous granulites, in which what appear to be relics of felspar pebbles are occasionally seen. Narrow bands of a semi-pelitic nature are of rare occurrence. At a few places, lenses and small bosses of dark hornblendic rock have been found. These are usually schistose, but are occasionally rather massive, and are presumably of igneous origin. Throughout its extent, the siliceous granulite is traversed by great numbers of acid stringers, veins, and small dykes, which form intricate complexes. About a mile S.W. of Achany Lodge a prominent knoll, consisting of white vein quartz much crushed and broken, rises out of the surrounding peat flat; a similar smaller knoll occurs some distance to the south-east.

Granites.—In the Migdale area and northwards by Loch a' Ghobhair and Loch an Lagain, Mr. Read has mapped a large mass of granite, which forms the crags of Migdale Rock, Craig a' Bhealaich and Creag a' Ghobhair, and covers an area of about six square miles. It is a non-foliated, fine-grained whitish rock with a small amount of biotite. On Migdale Rock, the granite is traversed by numerous contemporaneous pegmatites of an average width of 1 in. These seem to have been formed by exudation of the last juices of the granite magma into early

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joint planes in the already solid normal rock. The direction of the joints is N. 10 E—S. 10 W. Later still seem to be narrow quartz veins which run N. 10 W.—S. 10 E.; these later veins have occasionally pegmatite at their margins and quartz at their centres.

On its western and southern margins the Migdale Granite has a sharp junction with the Moine granulites; the granite is welded to the foliation planes of the granulite, which is little altered, possibly because it had already reached so high a degree of mineral stability. On the eastern and northern margin, however, no definite line can be drawn for the junction, for here a thorough complex of granite apophyses and granulite is found, which forms a belt half a mile or so in width outside the solid granite.

At Beinn Donuill, 5 miles N.E. of Bonar Bridge, a basic margin to the granite is seen. In parts the basic mass is composed of a very coarse black hornblende-biotite-rock of a scyelitic nature; with this are associated hornblende-biotite-rocks with patches of pink felspar; other types show approaches to granite. There is here little doubt that the scyelite and associated hybrid rocks belong to the Migdale Granite intrusion. The importance of this fact will be seen immediately in the discussion of the Ach'uaine hybrid rocks.

Part of the Lairg-Rogart Granite falls within the area surveyed. Mr. Haldane notes that in the Fleet valley the rock is an unfoliated coarse-textured biotite-granite, with occasional patches of dark basic material. This granite passes eastwards into the somewhat paler type seen at Dalmore.[1] This intrusion is separated from the Moine granulites by a well-marked belt of crush with a N.W.—S.E. direction which has determined the course of the Fleet valley at Acheille.

Rocks probably of hybrid origin.—At Ach'uaine (Gælic—green field), 2½ miles N.N.E. of Bonar Bridge, the vivid green herbage of the fields makes a striking contrast to the heather-clad ground occupied by the siliceous granulites and Migdale Granite. On examination, Mr. Read finds this to be due to the occurrence of ultrabasic and associated rocks at this locality. These rocks form a series of detached, elongated, irregular masses on the ground around Ach'uaine and Ledsaurich. They have also been met with further north around Cnoc a' Choire Bhuidhe by Mr. Haldane. From Ach'uaine a broken belt runs north for nearly a mile to Asdale. Near Ledsaurich another belt runs for about a mile with an average width of 100 yds.

Until a thorough microscopic examination of these rocks has been made, little beyond the impressions formed in the field can be given. The rocks of these basic masses are regarded as mixed rocks formed from two types, an ultrabasic scyelite type and a granite type resembling the Migdale granite. The

[1] *Vide* 'Summary of Progress for 1909' (*Mem. Geol. Surv.*), 1910, p. 41.

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scyelite is a hornblende-biotite-rock with large plates of black mica often 2 cms. across; the granite is a pinkish very fine-grained rock with scarce and small biotites. It is considered that, by the mixture of these two types, sometimes as magmas, sometimes by incorporation of ultrabasic in acid magma, sometimes by penetration of almost solid ultrabasic material by acid magma, there have been produced the innumerable varieties of mixed rocks seen in these masses. Some of these mixed types are :—

(1) Hornblende-biotite-rock with large patches of pink felspar.

(2) Finer grained rocks of similar composition to (1).

(3) Streaky rocks formed by inclusion of hornblende-biotite-rock in a granite base.

(4) Purplish ' acidic ' types with large plates of biotite.

(5) Innumerable mixtures formed by the intrusion of granite into scyelite without assimilation.

Mr. Dinham has found what appear to be rocks related to those just described at a locality 150 yds. south of the top of Lamentation Hill in Ross-shire.

Lamprophyres.—Mr. Haldane has recorded a lamprophyre dyke on the summit of Sithean Mor, 1 mile east of Invershin. This dyke trends almost due east-and-west and can be traced for over a quarter of a mile, and is possibly the continuation of that noted by Mr. Dinham on Lamentation Hill in Ross-shire (*see* above, p. 44). It cannot be traced far east of Sithean Mor. It is a quite unfoliated dark massive rock with abundant large plates of black mica. It contains many inclusions of Moine granulite and of granite (Migdale Granite?), which stand out as knobs on the weathered surfaces. Similar lamprophyre dykes have been found by Mr. Read at Creagan Reamhar, Garbh Leathad, Allt na Feith Moire and Allt na h' Atha. That these lamprophyres are later than the Migdale Granite has been proved by Mr. Read's discovery of a lamprophyre dyke cutting the granite at Loch Leisgin.

Old Red Sandstone.—At the eastern edge of Sheet 102 and south of Strath Fleet a small faulted-in patch of flaggy red sandstone has been noted by Mr. Haldane. Granite occurs both to the north and to the south of this patch but no actual boundaries are seen. The sandstone dips at 30° to the south-east, and is probably the termination of the Old Red Sandstone belt shown in Sheet 103, which may be here cut out by the large N.W.–S.E. fault already mentioned as occurring in the Fleet valley.

Pleistocene and Recent.—On the north-east shore of the Kyle of Sutherland, between Bonar Bridge and Linsidemore, there is a well-marked 50-ft. beach which, when traced up the Oykell valley, displays features similar to those described above by

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Mr. Dinham for the beach on the south-west side of the Kyle. There are also traces of a lower shelf at about 25 ft.

Coalfield Revision.

3. North Ayrshire Coalfield.

Field-work was mainly carried on in the volcanic district of Sheet 22. Mr. Anderson was engaged in the completion of coalfield maps commenced by the late Mr. C. T. Clough and himself. A boring for coal was visited near Rankinstone, and replies were furnished to enquiries from colliery managers entailing field observations in the Troon and Dalmellington districts.

The revision of the Calciferous lavas of the Clyde plateau has been continued by Mr. Richey and Mr. Burnett in the hill country between Stewarton and Mearns. Chief interest centres in a great spread of trachytes,[1] of which 8 square miles have now been mapped. It is probable that most of these trachytes are lava flows, though this conclusion is based on somewhat sparse observation of vesicular tops, unchilled margins, and intercalated beds of tuff. The stratigraphy of the area is especially difficult to work out, as the country is of low relief, with scarp-featuring ill developed; added to this there is extensive faulting and also an original discontinuity of the various lava zones, some of which were referred to in last year's 'Summary of Progress.' It can, however, be definitely stated that the widespread top Dalmeny Group of last year's classification continues eastwards through the uplands north of Fenwick, and is underlain by trachytes, to some extent associated with mugearite and various types of basalt, and that this assemblage is in turn underlain by a thick group of macroporphyritic basalt lavas. Considerable areas of trachyte occurring to the east of the Mearns–Fenwick road appear to be overlying the continuation of what is elsewhere the top group of Dalmeny basalts, but their mapping is incomplete. In this connection it may be mentioned that evidence of an acid phase posterior to the Dalmeny Group is afforded in other parts of North Ayrshire by the occurrence of abundant felsitic pebbles in the volcanic detrital beds that form the base of the Calciferous Sandstone sediments overlying the lavas.

4. Stirlingshire and Clackmannanshire.

The revision of the Stirling and Clackmannan area of Carboniferous rocks was continued during the spring and autumn by Messrs. Dinham, Read and Haldane, and that of the Douglas area by Mr. Macgregor. In addition to the normal field work short visits were paid to different localities in connection with

[1] J. E. Richey, 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 27.

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various 6-in. maps of the Central coalfield in course of publication. Borings for coal and ironstone in the districts of Barrhead, Glasgow, Airth, Bo'ness and Douglas were also examined during the course of the year.

STIRLINGSHIRE.

Mr. Dinham, in continuation of his work on the Lower Limestones on the north side of the Central coalfield,[1] began a re-examination of certain critical sections in the Corrie Burn district in 1-in. Sheet 31. The discovery in the middle burn of a representative of the "sandy encrinital limestone of Campsie," which occurs between the Hurlet and the Blackhall Limestones, is worth recording. This bed had previously been discovered in the Shields and Bannock burns,[2] but had not been recognised at Corrie, which lies between them, doubtless owing to the fact that the limestone is everywhere decalcified and resembles an ochreous sandstone. Its position in the Corrie sequence is shown in the following table :—

	Ft.	in.
Gap	—	—
Sandy LIMESTONE with occasional encrinites, &c.; the bottom 15 in. consists of thin beds very full of various marine fossils. Thickness apparently about	6	—
Gap about	5	—
Faky blaes	1	—
Sandstone, flaggy false-bedded	1	6
Sandstone, thin bedded and colour-striped	2	—
Gap	5	—
HURLET LIMESTONE seen here	7	—

The decalcified limestone is seen again 100 ft. further to S.W., at the east corner of an old quarry in the Hurlet Limestone.

In 1-in. Sheet 39 Mr. Dinham was engaged on the survey of the ground lying south and east of Stirling. The chief points of interest in the surface geology are :—

> (i) The discovery at Craig Moss, 3 miles S.E. of the town, of a hitherto unmapped 'islet' of rock in the middle of the Carse flats. (ii) The presence of large erratics of Highland grits of Ben Ledi type, and of Old Red Sandstone conglomerate, on the slopes of Dunmore Hill. (iii) The tracing of the old coast line of the '100-ft.' raised beach. The inner margin of this beach appears to rise to at least 145 ft. above O.D., and is fringed by terraces of sand and gravel which at Cambusbarron attain a thickness of at least 50 ft. Around Carnock and Castleton the old coast line crosses the outcrop of the massive sandstones of the Millstone Grit. These now form conspicuous lines of crags

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, pp. 34-41.
[2] *Ibid.*, p. 38.

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—a phenomenon rare in the Millstone Grit of Scotland, and due in this instance to the removal of the usual boulder-clay cover by the waves of the old sea, on whose shore they projected as rocky reefs and islands. The sudden disappearance of these crags as the old coast line is followed towards the north-west, coincides with an abrupt passage, across a large fault, from Millstone Grit into strata of the Upper Limestone Group, in which sandstones are neither as thick nor as numerous. This fault has also been approached from the north side in the workings of Carnock Pits; its throw amounts to at least 200 fms., and it is probably a continuation of the big Campsie Fault, which separates the coalfields of South Stirlingshire from the lavas of the Kilsyth Hills.

CLACKMANNANSHIRE.

Coal Measures and Millstone Grit.

Mr. Read has begun the revision of the Alva, Menstrie and Alloa districts of the Clackmannanshire coalfield. A general section of this coalfield is given in one of the published sheets of vertical sections (Sect. 4, Sheet 5, Scotland, 1877). It illustrates the ground immediately adjoining Devon Ironworks (now Devon Colliery) about 1 mile south-east of Alva, and shows at the top 72 ft. of red sandstone assigned to the Barren Red Measures. These beds are seen in the quarries around Devon Colliery, in the railway cutting near Black Row, and probably also in the Silver Glen, 500 yds. east of Alva Church. They are coarse reddish false-bedded sandstones and occupy the centre of the northernmost basin of the Clackmannan field. Their correlation with the Barren Red Measures is still open to doubt since sandstones of very similar type occur in this district within the limits of the Productive Coal Measures.

Abandoned shafts of which no records exist are very common in the Clackmannanshire field, coals and ironstones, both clayband and blackband, having been wrought here from an early period. Some of the workings must be at least 125 years old; the clayband ribs above the Nine-Foot coal, for example, were mined for the long-abandoned Devon Ironworks (*circa* 1792–1856).

The Devon basin is limited on the north by the Ochil Fault. Good sections are seen in the Alva, Silver, Mill and Kirk burns, which drain the face of the Ochils, and these enable the position of the fault to be fixed with some accuracy. In Alva Glen, Lower Old Red volcanic rocks are brought against smashed and upturned red sandstones of Carboniferous age. In the Silver Glen, the red sandstones already mentioned are seen to overlie white sandstone, blaes and fakes with thin coals dipping steeply south off the fault. Between the volcanic rocks and the Carboniferous sediments there is a dolerite intrusion which presents chilled edges to the volcanic rocks, and is crushed on its south side against the Carboniferous. In the Mill Burn, blaes, fakes

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and sandstone are almost vertical against the fault. A dolerite intrusion is found between the volcanic rocks and the Carboniferous, but here it appears to have chilled margins on both sides. In the Kirk Burn again the dolerite shows a chilled margin against the volcanics while it is smashed and broken along its junction with the sediments. It seems probable, therefore, that there has been repeated movement along the line of the Ochil Fault. It is still a notable line for earthquake tremors.

Along the western side of the basin, at the margin of the 50-ft. terrace on the south side of the River Devon and east of Tullibody Bridge, coarse white friable sandstones occur, which are referable to the Millstone Grit Series. This view is confirmed by the fact that in Tullibody Mine, at the north end of Gunther's Wood, the Coalsnaughton Main Coal, lying near the base of the Coal Measures, was formerly wrought at the outcrop. Bores on Knowfaulds and on the ground east of Tullibody show that there also Millstone Grit strata are present at the surface.

Mr. Haldane has extended the revision of the Clackmannanshire coalfield to the Clackmannan and Kincardine-on-Forth districts. Part of the ground is occupied by much faulted strata of Coal Measures age, to the east of which the Millstone Grit forms the higher ground of Tulliallan Forest and Bath Moor. The only stream of importance in this area is the Black Devon and, apart from the numerous partial sections seen along its course, natural rock exposures are few. The Cherry and Splint Coals, with their associated strata, are seen in the Devon 400 yds. west of Mary Bridge to the north-west of Clackmannan, while the Coalsnaughton Main is exposed where the river flows along the north of Birkhill Wood, 2 miles north-east of the same town. The district contains very many old workings, of most of which no records can now be traced. Of the numerous disused sandstone quarries the one at Craigrie, a mile south-west of Clackmannan, is the most interesting, as it furnishes an excellent section of the Nine-Foot Coal. The details of this section are :—

	Ft.	in.
Grey fakes	6	–
Black blaes	–	6
Coal	–	8
Fakes	–	6
Coaly rib	–	1
Fakes with clayband nodules	–	8
Sandstone	–	4
Clayband ironstone	–	1
Sandy fireclay	–	3
Flaggy sandstone and fakes	4	6
Blaes with thin clayband ribs and nodules	1	11
,, ,, ,, ,, "mussels"	1	7
Black blaes with fish remains	–	3
Nine-Foot Coal, with 4-in. of parrot on top	9	–
Fakes	1	–
Massive, yellowish-white sandstone - At least	25	–

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Glacial and Recent.

Outside the limits of the 100-ft. raised beach the ground is covered by a thick mantle of boulder clay containing many boulders derived from the Ochil Hills and from the Highlands to the north-west (*cf.* above, p. 49). Striae observed on the volcanic rocks of the Ochils indicate a south-easterly ice-flow, but the marked east-and-west orientation of the drumlins near Clackmannan shows that there the movement was in conformity with the general movement of the ice through the Central Valley.

Around Alloa the 100-ft. beach is well developed. Its margin has now been traced, generally as a well-marked feature, from Tullibody to Kincardine-on-Forth. Its deposits are mainly sands and clays, and at Hilton Brick Works near Alloa, dark chocolate clay, 30 ft. thick, is being worked for the manufacture of bricks, sanitary ware, &c. Clays of the 100-ft. beach were also formerly wrought to the north of Clackmannan.

The River Devon, below Tillicoultry, meanders through the flat 50-ft. carse lands, composed of a stiff brown clay. Upon the carse well-marked deltaic cones have been formed by streams issuing from the Ochil Hills, and on these the villages are built. Where the Black Devon traverses the deposits of the 50-ft. beach to the south-east of Alloa, small specimens of *Cardium* and of *Mytilus* have been obtained from a shell-bed in some of the blue clays. This beach has been more or less distinctly followed as far as Kincardine.

A deep buried channel runs up the Devon valley between Menstrie and Tillicoultry, as described in Mr. H. M. Cadell's 'Story of the Forth' (Glasgow, 1913, p. 90). A boring at Glenochil Distillery, Menstrie, passed through 337 feet of surface deposits, and did not reach rockhead. The height of the surface at this locality is only 35 or 40 feet above O.D.

LANARKSHIRE.

In the Douglas Coalfield, Mr. Macgregor and Mr. Manson examined and measured a number of sections in the Carboniferous Limestone Series at Bankend. The Poneil Water at this locality, along with its tributary the Hagshaw Burn, furnishes a fairly complete sequence from the Index Limestone to the Ell Coal and from the Macdonald Coal down to the well-known *Productus giganteus* limestone near the top of the Calciferous Sandstone sediments. A large suite of fossils has been collected from the various members of the Lower Limestone Group, but pending detailed examination of this material their correlation is held over.

As a supplement to the short account of the Douglas coalfield given in the 'Summary of Progress for 1919' (pp. 31–4,) the sections of the Limestone Coal Group exposed in the Hagshaw Burn may be shortly summarised. The Index Limestone, formerly exposed near the mouth of the burn, can no longer be examined

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in situ, but loose rocks that remain resemble the exposure in the old quarry at Longhill Burn some 2 miles to the east. The section of the Smithy and Dross Coals, and of the strata below and above them, is as follows :—

	Ft.	in.
Faky sandstone	3	–
Coal	–	7½
Fireclay	1	–
Blaes	1	6
Parroty blaes	2	–
Coal	–	6
Coaly fireclay	–	6
Faky sandstone with rooty top	9	6
Sandstone and faky sandstone	6	11½
Fakes and faky blaes	2	3
Firm blaes	3	3
Soft dark blaes	1	3
Firm blaes	3	3
Smithy Coal	2	3
Dark fireclay	1	4½
Coal	–	4
'Horn' or Wild Gas Coal	–	6
Dross Coal	3	10
Sandy fireclay	–	10
White rooty sandstone with irregular ribs of blaes	3	9
Blaes	1	–
Parroty blaes	1	3
Blaes	2	11
Faky sandstone	–	8
Blaes	3	5
Irony 'kingle' (*i.e.*, hard sandstone) lenticular up to	–	6
Blaes	1	6

The details of the section of the Ell Coal are :—

		Ft.	in.
Sandstone roof		–	–
Ell Coal	Head Coal	2	9
	Dark fireclay	1	6
	Coal	1	–
	'Horn' or Wild Gas Coal	–	11
	Coal	1	7
White rooty ganister-like sandstone floor.			

No exposures of the Nine-Foot or Six-Foot Coals occur in the Hagshaw Burn, but it should be noted that there is a narrow troubled area to the south of the fault which cuts off the coals noted above at a point about 450 yds. from the junction with the Poneil Water. It is not yet certain in what part of the sequence these troubled beds lie. They are followed up-stream by a very

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fine exposure of the Macdonald Coal. The details of the section are :—

	Ft.	in.
Dark blaes with clayband nodules and ribs; *Lingula* predominant, some brachiopods	–	–
Clayband rib - - - - - - 2½ in to	–	4
Dark shelly blaes, with brachiopods, &c. - -	1	6
Layer of flattened shelly nodules of irony limestone	–	2
Dark shelly blaes - - - - - - - -	2	9½
Dark blaes, very shelly - - - - -	1	9
Limestone rib - - - - - - -	–	7
Dark blaes, very shelly - - - - -	1	8
Macdonald Coal: Coal - - - - -	2	–
Macdonald Coal: Dark Fireclay - - -	–	4
Macdonald Coal: Coal - - - - -	2	10
Fireclay and balls - - - - - -	3	2
Dark parroty blaes with *Lingula* - - - -	1	–
Faky sandstone - - - - - 1½ ft. to	3	–
Blaes and hard fake ribs - - - - -	8	6
Fakes, faky sandstone and blaes - - at least	13	6½

There is a break in the sequence here but the Top Macdonald Limestone is not far below the base of the section just quoted. The marine beds overlying the Macdonald Coal, and the Lingula band which occurs a few feet below it, are very useful horizons in identifying the seam in the workings. Another exposure of the Macdonald Coal is seen in the Poneil Water nearly five-sixths of a mile east of the ford at Brockley; here it shows :—

	Ft.	in.
Shelly blaes (several feet thick) - - - - -	–	–
Coal - - - - - - - - - -	1	6
Fireclay - - - - - - - - -	1	0
Coal - - - - - - - - - -	–	7
Fireclay - - - - - - - - -	–	8
Coal - - - - - - - - - -	–	7½
Fireclay - - - - - - - - -	3	6

The attenuation of the seam in an easterly direction is also a characteristic of all the higher coals; on the eastern margin of the Douglas-Ponfeigh coalfield, however, they appear in still thicker development.[1]

The Macdonald Limestones are exposed at several localities and from the blaes associated with the highest of these *Posidonomya corrugata* has been obtained. The Hawthorn or Main Limestone is also seen at various places in the Poneil Water and Hagshaw Burn, and shows 6 or 7 fathoms of very fossiliferous nodular limestones and limy fakes, containing *Lithostrotion* bands, large *Producti* and corals. A 6-in. or 7-in. coal underlies it, while above it are 4½ ft. of faky sandstone and 2 ft. of a very white ganister-like sandstone with a nodular top. This sandstone

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 33.

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forms an exceedingly useful index in working out the details of the various partial sections. On top of it occurs a lenticular sandy ironstone, apparently worked in former days. This band reaches a thickness of 8 in. but is often absent; above it comes a slaty pyritous rib about ½ in. thick containing fish remains, and forming the base of a thick series of dark crumbling fossiliferous blaes.

5. Borings for Oil at D'Arcy and West Calder.

Periodical visits to the experimental borings for oil have been continued and the samples of sediments and pieces of rock have been examined by Mr. Tait.

D'Arcy Oil Well (1-in. Sheet 32 Scotland, 6-in. Sheet, Edinburgh, VIII., S.E.).—This boring, situated about 1 mile S.S.W. of the mining village of Chesterhill (3 miles S.E. of Dalkeith) commences in the Lower Limestone Group where it rises in a clearly defined anticline that forms a local fold along the general anticlinal uplift between the Roman Camp and Cousland on the eastern side of the Midlothian Coal Basin. South of the boring the anticline is crossed by a fault and several others have been proved in colliery workings both to the east and west of the local anticline.

The boring commences a few feet below the outcrop of the D'Arcy Limestone (No. 2 or Skateraw Limestone), the outcrop workings forming a semicircle round the site of the boring. At a depth of 27 fathoms it passes through limestone beds containing marine shells interbedded with sandstones and then continues in an alternating series of shales, sandstones, fireclays and marls to a depth of 117 fathoms. At 118 fathoms there occurs an oil-shale, approximately 15 ft. thick, and resting on a sandstone that gives off a large quantity of gas. The commercial value of the oil-shale cannot be estimated from the samples obtained by the method of drilling, but there is little doubt that it is one of the bands towards the top of the Oil Shale Group.

From 118 fms. to 150 fms.—the present depth of the boring —the strata are mainly sandstones, with a band of white limestone, 10 ft. thick at 126 fms. Traces of a coal occur at 139 fms. At 150 fms. a fine-grained white sandstone yields brackish water with traces of oil.

West Calder Oil Well.—In the 'Summary of Progress for 1919' an account of this boring was given to a depth of 543 fms. The present depth is 651 fms., the strata between 543 fms. and 650 fms., consisting of black shales with interbedded bands of volcanic ash. The boring is now in sandstone yielding salt water in considerable quantity. The absence of sandstones between 215 and 650 fms. is remarkable and it would appear that sandstones of the Granton Sandstone Group have not yet been reached.

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III.—PETROGRAPHICAL WORK.

1. England and Wales.

As far as England and Wales are concerned most of the petrographical work has been in connection with special enquiries from private individuals and Government departments. An investigation into the size and nature of dust-particles aspirated from the air of mines and factories has been carried out at the request of the Home Office, and the results will be in due course embodied in the reports of that department. Dr. Thomas at the invitation of the Society of Antiquaries has investigated the probable source of the 34 foreign stones that constitute all that remains of the inner circle and inner horse-shoe of Stonehenge. These stones have come within the purview of many geologists, who have suggested in general terms possible sources in North and South Wales, Devon, Cornwall, and even Scotland. They were simple standing-stones, not capped by lintels, and show no signs, except in the case of one prostrate stone, of ever having been morticed, as are the sarsens of the outer circle and the trilithons. That they were dressed on the spot and considerably reduced in size has been abundantly proved by the copious fragments found in the soil during the recent excavations by H.M. Office of Works.

The most interesting feature of these stones is that of the 34 now remaining, 29 are all of the same type (blue stones) and are formed of a bluish green even textured diabase that is characterised by an abundance of irregular felspar crystals (albite oligoclase) that appear in the hand-specimen as pinkish or white spots ranging from the size of a pea to that of a hazel nut.

This spotted character, not commented upon by earlier observers, at once removes the rock in question from the generality of diabases, and renders the identification of the source a matter of greater certainty.

A spotted diabase of identical appearance, mineralogical composition and microscopic character is the dominant rock of the Prescelly Mountains in Pembrokeshire. These hills rise more or less abruptly from the plain of Western Wales and owe their form and preservation largely to the sills of diabase which extend through them from Rosebush on the west to Crymmych on the east.

Such spotted diabases are, as far as Great Britain is concerned, practically restricted to the Pembrokeshire area and therefore the Prescelly Mountains must be regarded as the most probable ultimate source of the Stonehenge ' blue stones.'

It is interesting to note that in association with the spotted diabase of Prescelly there occurs a considerable mass of banded and minutely spherulitic rhyolites. These rocks, grey in colour and weathering with a white crust in which the banding shows most clearly, are identical with three stones of finely-banded

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rhyolite represented amongst the foreign stones of Stonehenge. It, therefore, appears that 32 out of the 34 foreign stones may, with little doubt, be referred to Pembrokeshire sources. The remaining examples of slaty sedimentary rocks and the micaceous sandstone of the so-called 'altar stone' are not in disagreement with a Welsh derivation.

As far as Salisbury Plain is concerned the foreign origin of these stones is unquestionable, and various theories have been propounded to explain their presence in a region so remote from all possible sources. The theory most generally accepted and first put forward by the late Prof. Judd, was to the effect that they had been transported by ice to the Plain from some region to the north; and he explained the absence of all smaller stones of the same character by assuming that these had been utilised for mill-stones, gate-posts, &c. As pointed out by Mr. Stevens and other workers, there is no evidence of the existence of any masses of rock of these types, either large or small, in Wiltshire, except within the area of Stonehenge itself. Further, the ice that was supposed to carry these boulders to Salisbury Plain would have had to select carefully from all the rocks over which it passed, not only as regards rock-type, but also as regards the size of the transported material. The idea that such rocks had been glacially carried to the Plain must be dismissed as being contrary to the mass of geological evidence. With the object of eliminating all other possible sources, especially those of a proximate nature, a careful revision was made of the rock-types represented amongst the large boulders stranded on the coastal regions of Hampshire between Selsey and Bournemouth. All specimens available including those noted by Godwin Austin, Clement Reid, Osborne White, and others, have been examined, with the result that in no case has a Stonehenge type been detected. We may assume, therefore, that these boulders, often of considerable size and occurring relatively near to Salisbury Plain were either unknown to, or disregarded by, the builders of Stonehenge. In view of the last-mentioned fact and the still more important uniformity of type presented by the Stonehenge 'blue stones' and rhyolites, the inevitable conclusion is that the stones were brought direct from their parent source by human agency.

In Pembrokeshire, boulders of these rocks, dislodged by the ice that passed over the Prescelly Mountains, lie scattered over the stopes and low ground to the south and south-east, and masses of suitable size could be easily collected. That the monoliths were derived from a glaciated region, a feature that at once rules out Devon and Cornwall as possible sources, is indicated by the recent find at Stonehenge of a large flake from one of the 'bluestones,' which shows good glacial striations.

2. Scotland.

Petrographical work in connection with the forthcoming memoir on the Island of Mull has been carried out by Dr. Thomas

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and Mr. E. B. Bailey. Special attention has been paid to the classification of the basalt lavas of Sheet 44. It has been found that they are roughly divisible into two petrographical groups olivine-rich and olivine-poor respectively. Of these, varieties rich in olivine preponderate in the lower part of the volcanic pile, and the olivine-poor varieties in the upper part.

In the Ben More region the group rich in olivine is roughly 3,000 ft. in thickness, and it is clear in the field that the group poor in olivine which succeeds is of approximately the same magnitude.

In previous reports the basalts poor in olivine have been spoken of as andesites, and this appellation has not infrequently been applied to certain olivine-rich varieties that have a pale tint in the hand-specimen. The prevalence of pale lavas associated with, but distant from, the mugearite lava-zone of Ben More was, perhaps, first recognised by Sir Archibald Geikie. The pale colour is now shown to be correlated with a poor development of magnetite which results from the decomposition of olivine. In the Ben More region it would seem that the olivine of the lavas in the lower part of the olivine-rich group of basalts was more ferruginous than that of lavas on higher horizons, for it yielded on decomposition abundant secondary magnetite. It is one of the most interesting features of Mull geology that within a circle 14 miles in diameter, none of the basalt lavas have retained their olivine in a fresh condition. This circle centres on the hill-country between Glen Cannel and Glen More, and includes Ben More well within its circumference. The definite character of this phenomenon will be recognised when it is said that out of 336 olivine basalts sliced from within the circle none has retained any fresh olivine, while of 44 specimens of similar rocks sliced from outside the area in question, 34 carry this susceptible mineral in a more or less unaltered condition.

Side by side with this replacement of olivine by chlorite and serpentine, there is a widespread development of albite and epidote filling cracks and vesicles. These phenomena are attributed to pneumatolitic action connected with the Mull centre of activity. A full discussion must be deferred until the publication of the Memoir, but it is proper to say that many of the features have already been dealt with in the writings of the late Prof. Judd.

IV.—CHEMICAL WORK.

During the year work in connection with the Special Report on British Refractory Materials has been continued, and 18 fireclay analyses completed for inclusion therein.

In addition, analyses were made of one rock from Leicestershire for Memoir Sheet 169 and of eight from Aberdeen and Banffshire for Memoir on Sheets 86 and 96, the details of seven being included in this Report.

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As examples of the composition of British fireclays analyses of six are given below :—

Old Mine fireclay, black, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4354; Lab. No. 610.

Old Mine fireclay, white, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4355; Lab. No. 611.

Fireclay, No. 1 New Mine, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4357; Lab. No. 613.

Fireclay, No. 4 New Mine, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4356; Lab. No. 612.

'*Nonsuch Fire-earth*'—brown-green variety, Reading Beds, Epsom.—One-in. Ordnance map (New Ser.), 286; 6-in. Surrey, 19, N.W. Museum No. 5703; Lab. No. 653.

'*Nonsuch Fire-earth*'—'white' variety, Reading Beds, Epsom.—One-in. Ordnance map (New Ser.), 286; 6-in. Surrey, 19, N.W. Museum No. 5709; Lab. No. 659.

Lab. No.	610	611	613	612
SiO_2	45·22	77·71	58·18	62·67
TiO_2	1·08	1·38	1·27	1·15
Al_2O_3	31.32	13·46	26·36	22·30
Fe_2O_3	1·76	1·04	1·61	2·90
MnO	·03	·02	·03	·03
CaO	·34	·05	·29	·23
MgO	·51	·23	·69	·66
K_2O	·94	·06	1·67	·48
Na_2O	·23	·35	·20	·38
Li_2O	trace	trace	trace	trace
H_2O at 105° C.	3·00	·91	1·56	1·61
H_2O above 105° C.	11·30	4·81	8·19	7·86
P_2O_5	·07	·05	·12	·07
FeS_2	·01	·05	·04	·02
Organic matter	4·18	·12	·21	·12
CO_2	·04	·03	·01	·04
Total	100·03	100·27	100·43	100·52
Loss on ignition	18·52	5·94	10·17	9·58

Lab. No.	653	659
SiO_2	85·65	91·30
TiO_2	·36	·35
Al_2O_3	5·44	3·77
Fe_2O_3	4·21	1·98
FeO	·23	·11
MnO	·03	·02
CaO	·40	·34

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Lab. No.	653	659
MgO	·65	·44
K_2O	1·19	·60
Na_2O	·10	·01
Li_2O	nt. fd.	nt. fd.
H_2O	1·98	1·32
P_2O_5	·05	·03
FeS_2	nt. fd.	nt. fd.
CO_2	nt. fd.	nt. fd.
Total	100·29	100·27

Results calculated on samples dried at 105° C.

The following are analyses of rocks of the Older Igneous Series of Portsoy and district :—

Pyroxenite.—Line of crags, inside west edge of Whitehill Plantation, 300 yds. W. by N. of Whitehill Farm; ¾ mile W. of Rothiemay Station. One-in. map, 86; 6-in. Aberdeen, 17, S.W. Slice No. S. 20363; Lab. No. 640.

Labradorite Rock.—Knob, just above high-water mark, 200 yds. W.S.W. of gasworks, Portsoy. One-in. map, 96; 6-in. Banff, 3, N.E. Slice No. S. 2213; Lab. No. 639.

Epidiorite.—Sea-cliff, 70 yds. W. of gasworks, Portsoy. One-in. map, 96; 6-in. Banff, 3, N.E. Slice No. S. 20364; Lab. No. 641.

Lab. No.	640	639	641
SiO_2	49·76	48·85	48·65
TiO_2	·11	·29	1·30
Al_2O_3	2·70	26·51	14·92
Fe_2O_3	2·56	1·28	1·31
Cr_2O_3	·34	nt. fd.	nt. fd.
V_2O_3	·07	nt. fd.	nt. fd.
FeO	4·26	·95	8·03
MnO	·17	·13	·11
(CoNi) O	nt. fd.	·03	nt. fd.
BaO	nt. fd.	·01	trace
CaO	15·56	12·19	8·79
MgO	22·03	1·64	8·92
K_2O	·18	·96	1·76
Na_2O	·10	3·64	2·56
Li_2O	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	·24	·25	·23
H_2O above 105° C.	1·85	1·57	1·26
P_2O_5	·05	·08	·17
FeS_2	nt. fd.	nt. fd.	nt. fd.
Fe_7S_8	nt. fd.	nt. fd.	1·07
CO_2	·05	1·96	·96
Total	100·03	100·34	100·04

Anal.—E. G. Radley.

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Below are four analyses of the Younger Igneous Series forming part of the Huntly Igneous Mass :—

Peridotite.—Quarry on east side of road, midway between Boghaugh and Broadlands, ⅓ mile N.E. of Broadlands, 3 miles W.N.W. of Huntly P.O. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 20360; Lab. No. 634.

Olivine Gabbro.—Right bank of River Deveron, 200 yds. N. of Cairnford Bridge, 2¾ miles W. by N. of Huntly P.O. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 19680; Lab. No. 635.

Troctolite.—Craighead Quarry, in wood N. of road, ⅓ mile E. of Cairnford Bridge, 2 miles W. of Huntly. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 20361; Lab. No. 636.

Norite.—Ladysmith Quarry, W. of Keillenknowes, 4 miles N.N.E. of Huntly. One-in. map, 86; 6-in. Aberdeen, 17, S.E. Slice No. S. 20362; Lab. No. 637.

Lab. No.	634	635	636	637
SiO_2	35·72	48·11	44·29	48·58
TiO_2	·36	·75	·09	3·44
Al_2O_3	10·99	17·86	25·26	13·82
Fe_2O_3	3·73	·43	·04	1·14
Cr_2O_3	·37	·13	·09	nt. fd.
V_2O_3	·09	·05	·03	nt. fd.
FeO	6·37	5·20	3·28	12·73
MnO	·06	·30	·25	·32
(CoNi) O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
BaO	trace	nt. fd.	trace	nt. fd.
CaO	3·28	12·42	11·32	9·43
MgO	26·62	9·53	7·94	5·21
K_2O	·43	·64	·49	·76
Na_2O	·58	2·34	2·30	2·87
Li_2O	nt. fd.	nt. fd.	trace	nt. fd.
H_2O at 105° C.	·58	·14	·33	·05
H_2O above 105° C.	8·72	·84	2·57	·36
P_2O_5	·14	·07	·07	·64
FeS_2	·12	·11	·12	·08
Fe_7S_8	1·49	·68	·95	·38
CO_2	·38	·54	·83	·37
Total	100·03	100·14	100·25	100·18

Anal.—E. G. Radley.

Quartz-Diorite Porphyrite.—Elongated boss, unconformably overlain by Keuper Marl and drift. N.W. corner of Sapcote Quarry. One-inch map 169. Six-inch Leicester, 43 N.E. Slice No. E. 12011. Lab. No. 633.

SiO_2	61·84
TiO_2	·66

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Al_2O_3	15·51
Fe_2O_3	1·90
FeO	2·84
MnO	·08
(CoNi)O	nt. fd.
BaO	·02
CaO	5·03
MgO	3·22
K_2O	1·98
Na_2O	4·12
Li_2O	nt. fd.
H_2O at 105°C	·34
H_2O above 105°C	1·97
P_2O_5	·21
FeS_2	·10
CO_2	·52
Total	100·34

Anal.—E. G. Radley.

V.—PALÆONTOLOGICAL WORK.

1. England and Wales.

The collections of fossils have been enriched by some valuable donations. Miss C. A. Raisin presented a large collection of Jurassic Mollusca, formerly in the possession of the late W. H. Hudleston. The specimens are well localized and are of fine quality, while many of them are of special interest, since they serve to illustrate some of Hudleston's published work. Mr. G. W. Lamplugh presented his fine collection of sponges from the Upper Chalk of Yorkshire. This comprises many specimens suitable for museum exhibition, and a wealth of material for special study. A collection of 500 specimens of Mollusca from the Crag of Oakley was received from Mr. F. W. Harmer.

Dr. Kitchin and Mr. Pringle examined several sections in the Gault of different localities. At Copt Point, Folkestone, they searched for the horizon characterised by the *catillus*-fauna, which occurs in the Rostratus Beds of sandy facies in Wiltshire and the Isle of Wight. It was found to occupy a position at Folkestone near the base of Price's Bed XI., about 15 ft. above the top of Bed IX. In a temporary opening made in an old clay-pit at Long Crendon, in Buckinghamshire, the clay was found to be Upper Gault, showing an ochreous basement-bed almost identical in character with that seen in the case of the overlapping Upper Gault near Leighton Buzzard, which there rests upon the uppermost parts of the Lower Greensand. At Long Crendon, the basement-bed occupies a position less than 3 ft. above a Purbeck limestone.

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Visits were also made to Cambridge, to examine a section in the Cambridge Greensand and Gault, and to the Leighton Buzzard neighbourhood, to continue observations on the Gault and contiguous deposits, begun unofficially by Dr. Kitchin and Mr. Pringle. At the Norman Cement Co.'s large pit at Cambridge, some excavations had laid bare the Cambridge Greensand, which is rarely so well seen. The phosphate-bed was observed to rest upon an uneven and bored floor of unfossiliferous Gault. It was not possible to determine the exact horizon of this uppermost Gault, but it is highly probable from its lithological characters and the absence of fossils in it, that it corresponds with a level well above the base of Bed XI. of Folkestone. This is in agreement with the observations made by Prof. Fearnsides many years ago in the Barnwell pit. The amount of erosion to which the Gault was subjected at these localities was, therefore, less than in some other pits at one time opened along the outcrop, where the phosphate-bed contained some of the fossils of Bed IX. of Folkestone, in *remanié* condition.

Further collecting of fossils from the nodules of the Tardefurcata Bed, below the Interruptus Zone south of Leighton Buzzard, has added considerably to our knowledge of the fauna of that horizon, which is there well characterised by species of *Leymeriella*. The results of collecting from the phosphate-nodules in the sands immediately below the Gault at West Dereham, Norfolk, favour the view that at that locality the Tardefurcata Zone is present below the Interruptus Clay, as in Bedfordshire.

Mr. Pringle visited the sites of numerous borings during the year. The results of the borings at Bourne End, Marlow and Slough have been incorporated in the Memoir on the Water Supply of Buckinghamshire and Hertfordshire. Upwards of a dozen borings in Norfolk have given interesting geological information, which has not yet been made available for publication. Light has been thrown on the underground extension of the Jurassic formations in that county. A boring at North Ferriby, near Hull, has shown that the Red Chalk there rests upon a clay which belongs either to the basal part of the Kimmeridge Clay, or to the upper part of the Corallian Series. The results of Mr. Pringle's examination of the cores at a deep boring at Yate, Gloucestershire, are published herewith as an Appendix (p. 92).

A piece of core from the Keele Beds in a boring at Slang Lane, Wellington, submitted to Mr. Pringle for examination, yielded a new insect-wing. This has been described by Mr. H. Bolton as *Archimylacris pringlei* in a paper read before the Geological Society.

Good progress has been made in museum revision-work. Mr. Buckman has continued the re-naming of the Jurassic ammonites. Mr. Chatwin has carried out curatorial work on

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the collection of Tertiary Mollusca, and has devoted much time to the important task of registration.

The following specimens in the Museum have been figured and described :—

In the Palæontographical Society's Volume for the Year 1918.

(Published 1920.)

A Monograph of the British Ordovician and Silurian Bellerophontacea. (Part 1.)

By Dr. F. R. Cowper Reed, M.A.

Sinuites anceps *Reed*, pl. i, figs. 1, 1a, 2, 2a, p. 5.
„ bilobatus (*J. de C. Sow.*), pl. i, figs. 8, 8a, b, p. 7.
„ elongatus (*Portl.*), pl. i, figs. 12, 12a, 13, 13a, p. 9.
„ semirugosus *Reed*, pl. ii, figs. 13, 14, 16, p. 13.
„ soudleyensis *Reed*, pl. ii, figs. 18, 18a, b; pl. iii, fig. 3, p. 13.
Oxydiscus acutus (*J. de C. Sow.*), pl. iv, figs. 1, 1a, b, 2, 2a, p. 19.
„ ? llanvirnensis (*Hicks*), pl. iv, figs. 10, 10a, 11, 11a, p. 22.
Cyrtolites nodosus (*Salt.*), pl. v, figs. 1, 1a-c, 2, 2a, b, p. 25.
„ „ *var.* llandoveriana *Reed*, pl. v, figs. 3, 3a, 4, p. 26.
Kokenospira lingualis (*Salt.*), pl. vi, fig. 16; pl. vii, figs. 1, 1a, b, p. 35.
Tetranota hippopus (*Salt.*), pl. viii, fig. 16, p. 43.

The Pliocene Mollusca of Great Britain. Volume ii., Part 1.

By Mr. F. W. Harmer, M.A.

Scala (Spiniscala) trevelyana (*Leach*), pl. xlviii, fig. 14, (2 views), p. 528.
„ (Lamelliscala) frondosa (*J. Sow.*), pl. xlviii, fig. 22, (2 views), p. 532.
Pyrgulina scalaris (*Philippi*), pl. xlix, fig. 43, (2 views), p. 577.
„ spiralis (*Montagu*), pl. xlix, fig. 44, (2 views), p. 578.
Alvania (Massotia) lactea (*Michaud*), pl. l, fig. 41, (2 views), p. 621.
„ (Galeodina) carinata (*Da Costa*), pl. l, fig. 44, (2 views), p. 620.
Manzonia costata (*Adams*), pl. l, fig. 48, (2 views), p. 624.

In the Quarterly Journal of the Geological Society Volume LXXVI.

By Dr. F. J. North.

Tylothyris laminosa (*M'Coy*), pl. xiii, fig. 16, p. 197.
Spirifer plicatosulcatus *North*, pl. xiii, figs. 17a, b, p. 193.

In the Geological Magazine, Volume LVII., 1920.

By Dr. F. R. Cowper Reed, M.A.

Homalonotus (Burmeisterella) elongatus (*Salt.*), p. 343.

In the Annals and Magazine of Natural History, Volume V.

By Dr. C. W. Andrews, F.R.S.

Patanemys bartonensis *Andrews*, text-fig. 2, p. 149.

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IN TYPE AMMONITES, VOLUME iii.

By MR. S. S. BUCKMAN.

Retenticeras retentum (*Simpson*), pl. clxvi, figs. 1, 2.
Pavloviceras bathyomphalum *S. Buckm.*, p. 18.
„ omphaloides (*J. Sow.*), p. 18, (2 specimens).

IN THE REPORT OF THE YORKSHIRE PHILOSOPHICAL SOCIETY, 1919.

British Fishes and Reptiles—Pliocene to Holocene.

By MR. ALFRED BELL.

Notidanus griseus ? *Cuv.*, pl. i, fig. 4, p. 9.
Acipenser toliapicus *Ag.*, p. 12.

IN THE ANNALES DE LA SOCIÉTÉ GÉOLOGIQUE DU NORD, LILLE, TOME XLIII.

By DR. P. PRUVOST.

Leaia salteriana *R. Jones*, pl. ii, figs. 1–3; text-fig. 2, p. 262.

2. SCOTLAND.

Fossils were collected from Carboniferous Rocks in the Central coalfield, and from Mesozoic areas in the island of Mull and Sutherlandshire.

The Carboniferous fossils were obtained partly from natural exposures and partly from borings. In several instances the determination in borings of important horizons, about which there was doubt, was successfully achieved from palæontological evidence.

A preliminary examination of fossils collected by Mr. Manson on the west coast of Mull has led to the recognition of Rhaetic, Hettangian, and Sinemurian strata referred to on p. 35.

Detailed collecting, on zonal lines, was made in the Jurassic rocks of the Brora district in Sutherland, but as the work was undertaken late in the year, the critical examination of the fossils could not be begun in time to be summarised here.

VI.—PHOTOGRAPHIC WORK.

In England and Wales 26 views of geological subjects have been added to the collections.

In Scotland 170 negatives of landscapes of special geological interest in the counties of Argyll, (Morvern and Mull), Forfar and Kincardine were obtained.

VII.—MUSEUM OF PRACTICAL GEOLOGY.

In illustration of Vol. VII. of the 'Special Reports,' a temporary exhibit has been prepared of the lignites, jets, Kimmeridge oil-shale, mineral oils and cannel coals of Great

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Britain. This exhibit, which includes a sample of the oil from the Hardstoft boring in Derbyshire, has been the object of much public interest.

Dr. J. Morrow Campbell lent a large suite of specimens in illustration of his paper on the Tungsten Deposits of Burma, and Mr. W. S. Lockhart has lent a Chinese screen, which is a very beautiful example of skilful artistic treatment of a colour-banded slate.

Although much work is still necessary before the Museum recovers from the disorganisation caused by the war, it has been possible this year to make all parts accessible, and the work of arrangement is now in progress.

List of Donations during the year 1920.

Acton, A., Esq.—Two nodules from sandy limestone shales, also sections and specimens of silica.

Anderson, Dr. Victor C.—Specimen of oil shale from Grand Valley, Colorado, with photographs.

Andrews, Charles T., Esq.—Specimens of phenakite crystals, also enhydros, from Brazil.

Barrow, Mrs. R.—A fine specimen of *Ammonite* from the Mammillatus Bed of West Dereham, Norfolk.

Bolckow, Vaughan & Co., Messrs.—A specimen of fused silica-brick, also akermanite crystals.

Brown, G. F., Esq.—A specimen of *Lima hoperi* Mant., from the Upper Chalk of Purley.

Buck, the Hon. E. C., M.Inst.C.E., F.G.S.—specimens of petroleum (pitch) from the Waini and Pomeroon districts, British Guiana.

Carley, G., Esq.—A fine group of pyrites crystals from the Gaurano Mine, Tuscany.

Carruthers, R. G., Esq., F.R.S.E.—Two specimens and a series of thin sections of *Cryptophyllum hibernicum* R. Carr., from the Carboniferous Limestone of Bundoran, Donegal Bay, Ireland.

Dewey, H., Esq., F.G.S.—Specimens of marcasite and pseudomorphs, also ancient slags.

Edge, Lieut. A. B.—A specimen of siliceous sinter, from Devonshire.

Garnett, C. S., Esq.—Two small specimens of red fluorspar from Ashover.

Gomme, A. T., Esq.—Part of a dermal spine of *Polacanthus*, from the Wealden of Cuckfield, Sussex.

Greenly, Dr. E.—A specimen of Asteroid from the Middle Calcareous Grit of Filey Brig, Yorkshire.

Hackney, Noel G., Esq., M.Inst.M.M.—A drawing of the Southampton Common Well, by Henry Penrose, Engineer, 1842, showing strata to 560 feet. Scale, 1 inch—4 feet.

Hall, T. Clifford, Esq., Assoc.M.Inst.M.M., F.G.S.—Minerals and rock specimens from Abyssinia; also specimen of tin vein from Roche, Cornwall.

Harmer, F. W., Esq., M.A., F.G.S.—A large series of Crag Mollusca from Oakley, Suffolk.

Holloway & Co., Ltd., Messrs. G. T.—Cobaltite from the Cloncurry district, Queensland, Australia.

Hooker, Lady.—Copper ore and graphite from Sikkim.

Kidner, N. W., Esq.—A fragment of upper jaw of the crocodilean genus *Steneosaurus*, from the Cornbrash near Thrapston.

King, W. B. R., Esq., M.A., F.G.S.—Seven specimens of *Griffithides shunnerensis* King, from the Millstone Grit of Shunner Fell Well, near Hawes, Yorkshire. Also 6 specimens of volcanic rocks from the Rhine valley.

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KITCHIN, F. L., ESQ., M.A., PH.D., AND PRINGLE, J., ESQ., F.G.S.—A series of fossils and rock-specimens from the Lower Greensand, Gault and Cenomanian of the Leighton Buzzard district.

LAMPLUGH, G. W., ESQ., F.R.S.—A large suite of fossils (mostly sponges) from the Upper Chalk of Yorkshire and a few fossils from the Red Chalk of Yorkshire.

LAVER, H. E., ESQ.—Two boxes of Chinese paints.

LEIGH, THE RIGHT. HON. LORD.—Specimens of pyrrhotite from Griqualand.

LIBERIAN DEVELOPMENT CO., THE.—Specimens of phenakite sand from Liberia.

MARSHALL, FRANCIS, ESQ.—Pyrites on quartz.

MAYO, H. J. A., ESQ.—A fossil cone from the Ferruginous Sands of Shanklin, Isle of Wight.

MERRICKS, FRANK, ESQ., C.B.E., A.R.S.M.—A gold nugget with crystal faces, mounted as a pin.

MESOPOTAMIA, THE CIVIL COMMISSIONER IN.—A set of economic rock specimens from Mesopotamia and Southern Kurdistan. (Collected by A. H. Noble, Esq.).

NEWBOLD, MRS. ELEANOR T.—Model of a silver mine at Guanajuato, Mexico.

OSMAN, C. W., ESQ.—Crystals of inyoite from New Brunswick. Granite specimens from boring at 'Ontie Down,' Chagford. Model of twin crystal of pyrites.

OWENS, DR. J. S., F.G.S.—A fine example of artificial percussion cones in flint.

PAIN, MESSRS. A. C. D., AND R. S.—Three quartz pseudomorphs after octahedral scheelite crystals, from South Zeal, Sticklepath, Okehampton, Devonshire.

PENTLAND, THE RIGHT HON. LORD.—A walking stick of black limestone, silver mounted, with inscription 'Presented to H.E. Lord Pentland by D. Kristna Rao.'

PERKIN, DR. F. MOLLWO, C.B.E., PH.D., F.I.C.—Specimens of calcite from Nottingham.

PICKERING, CAPT.—Specimens of 'boxstone' from Wiltshire.

PRINGLE, J., ESQ., *see* KITCHIN, DR. F. L.

RAISIN, MISS C. A., D.SC., F.L.S., F.G.S.—A fine collection of about 4,000 fossils, chiefly Jurassic mollusca, formerly in the possession of the late W. H. Hudleston, F.R.S.

REINHOLD, DR. TH.—Two specimens of limestone used for lime at Maastrict and Kinrade, Holland.

RENWICK, R., ESQ.—Specimen of Stammarhan roofing stone; paving stone with ripple marks; paving stone with circular casts.

RODDA, MRS. (per W. WHITAKER, ESQ.)—Felspar twin.

SANDERS, A. B., ESQ.—Specimen of manganese ore from Brazil.

SCHAVERIEN, —., ESQ.—Three specimens of black spinel: (*a*) raw material, (*b*) cut but unpolished, (*c*) polished.

SMITH, BERNARD, ESQ., M.A.—Specimens of blende and calcite from Shropshire.

SOAMES, E. R., ESQ.—Specimens of *Stigmaria ficoides* from the Ganister of Wolsingham.

SOUTH DURHAM, STEEL AND IRON CO., LTD.—Specimens of slag, etc.

STAMP, L. DUDLEY, ESQ., M.SC.—Three specimens of associated lead and zinc ores from Lontzen Mine, Belgian Prussia.

STRAHAN, SIR AUBREY, K.B.E., F.R.S., etc.—Calamine from Holywell, and hæmatite from the Coal Measures near Frizington.

TEMPEST, P. C., ESQ., C.B.E., M.INST.C.E.—A series of photographs of the landslip in Folkestone Warren, with descriptive map.

WARREN, A., ESQ.—Specimen of picrite from Knowle Hill, Newton Abbot, Devon.

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WARREN, S. HAZZLEDINE, ESQ., F.G.S.—A series of specimens, mostly fossils, from certain wells in or near London. A large rough-worked block from the implement-bearing scree, Graig Lwyd, near Penmaenmawr; also a more finished but imperfect implement. Also two Roman blocks of calcareous tufa from East Wear Bay.

WHITAKER, W., ESQ., B.A., F.R.S.—A necklace of clear facetted amber beads.

WAY, REV. DR. J. P.—A specimen of pseudomorphous quartz from South Zeal Mine, Cornwall.

WHITE, FRANKLIN, ESQ., M.INST.M.M.—Mineral specimens from Broken Hill, Rhodesia.

WILSON, M. E., ESQ.—A series of samples representing the products of the Canadian China Clay Company, Amhurst Township, Ottawa, Canada.

WRIGHT, C. S., ESQ.—A twinned crystal of albite.

VIII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MAPS.

SIX-INCH REFERENCE MAPS.

The following 24 standard copies of Six-inch quarter-sheets have been made from the field copies, and are available for reference :—

Hertfordshire, 19 S.E.; 20 S.W., S.E.; 27 N.E., S.E.; 28 N.W., N.E., S.W., S.E.; 34 N.E., S.E.; 35 N.W., N.E., S.W., S.E.; 39 N.E., S.E.; 40 N.W., S.W.

Kent, 8 S.W.

London, 8 S.W., S.E.

Middlesex, 1 N.E., S.E.

II.—MEMOIRS.

PUBLISHED MEMOIRS.

Special Reports on the Mineral Resources of Great Britain :—

Vol. VI.—Refractory Materials: Ganister and Silica-Rock—Sand for Open-Hearth Steel Furnaces—Dolomite. Resources and Geology. 2nd Edition. 241 pp.; 3 plates; 8 text-figures. 1920. Price 7*s.* 6*d.* net.

Vol. VII.—Mineral Oil, Kimmeridge Oil-Shale, Lignites, Jets, Cannel Coals, Natural Gas. England and Wales. 2nd Edition. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., with contributions by W. Gibson, D.Sc., H. Dewey, B. Smith, M.A., C. E. N. Bromehead, B.A., J. Pringle. 125 pp.; 1 plate; 7 text-figures. 1920. Price 5*s.* net.

Vol. XII.—Iron Ores (*contd.*): Bedded Ores of the Lias, Oolites and Later Formations in England. By G. W. Lamplugh, F.R.S., C. B. Wedd, B.A., and J. Pringle. 240 pp.; 8 plates; 12 text-figures. 1920. Price 12*s.* 6*d.* net.

Vol. XIII.—Iron Ores (*contd.*): Pre-Carboniferous and Carboniferous Bedded Ores of England and Wales. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., W. Gibson, D.Sc., T. C. Cantrill, B.Sc., R. L. Sherlock, D.Sc., and Henry Dewey. 123 pp.; 3 plates, 10 text-figures. 1920. Price 7*s.* 6*d.* net.

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Vol. XIV.—Refractory Materials: Fireclays. Resources and Geology. 243 pp.; 4 plates, 13 text-figures. 1920. Price 8*s.* net.

Vol. XV.—Arsenic and Antimony Ores. By Henry Dewey, with contributions by J. S. Flett, O.B.E., LL.D., D.Sc., F.R.S., and G. V. Wilson, B.Sc. 59 pp.; 1 plate, 2 text-figures. 1920. Price 3*s.* net.

Vol. XVI.—Refractory Materials: Ganister and Silica-Rock—Sand for Open-Hearth Steel Furnaces—Dolomite. Petrography and Chemistry. By Herbert H. Thomas, M.A., Sc.D., A. F. Hallimond, M.A., and Ernest G. Radley. 115 pp; 7 plates, 6 text-figures. 1920. Price 5*s.* net.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1919. 70 pp.; 3 text-figures. 1920. Price 2*s.* 6*d.* net.

The Geology of Anglesey. By Edward Greenly. 980 pp., 60 plates; 17 folding-plates, 246 text-figures. 1919. In two volumes. Price 3*l.* 3*s.* net.

SCOTLAND.

I.—Maps.

Six-inch Reference Maps.

The following copies of 6-inch maps have been completed and deposited in the office for reference :—

Aberdeen, 34 N.W., N.E., S.W., S.E.; 35 N.W., N.E., S.W., S.E.; 43 N.W., N.E.; 44 N.W., N.E.
Renfrew, 15 N.E.
} Solid and Drift of each.

The revision work of the Silurian areas of the Southern Uplands of Scotland has been added to the following 6-inch clean copies (Old Series Maps) and these are now completed and deposited in the office for reference :—

Kirkcudbright, 30 N.W., N.E., S.W., S.E.; 35 N.E., S.E.; 36 N.W., N.E., S.W., S.E.; 37 N.W., N.E., S.W., S.E.; 42 N.W., N.E., S.E.; 43 N.W., N.E., S.W., S.E.; 48 N.E.

Wigtown, 1 S.W., S.E.; 2 S.W., S.E.; 3 S.W.

II.—Memoirs.

Published Memoirs.

Summary of Progress for 1919. *See* above.

Special Reports on the Mineral Resources of Great Britain :—

Vol. XI.—Iron Ores (*cont.*): The Iron Ores of Scotland. By M. Macgregor, B.Sc., G. W. Lee, D.Sc., G. V. Wilson, B.Sc., with contributions by T. Robertson, B.Sc., and J. S. Flett, F.R.S. 240 pp; 18 text-figures. 1920. Price 10*s.* net.

The Economic Geology of the Central Coalfield of Scotland. Area IV. Paisley, Barrhead, Renfrew, and the Western Suburbs of Glasgow North and South of the Clyde. By L. W. Hinxman, B.A., F.R.S.E., E. M. Anderson, M.A., B.Sc., and R. G. Carruthers, F.G.S. 110 pp.; 8 plates, 5 text-figures. 1920. Price 6*s.* net.

The Economic Geology of the Central Coalfield of Scotland. Area VII. Including the Districts of Rutherglen, Hamilton and Wishaw. By the late C. T. Clough, M.A., LL.D., the late J. S. G. Wilson, E. M. Anderson, M.A., B.Sc., and M. Macgregor, M.A., B.Sc., with contributions by R. G. Carruthers and C. H. Dinham, B.A. 144 pp.; 6 plates, 4 text-figures. 1920. Price 7*s.* 6*d.* net.

The Mesozoic Rocks of Applecross, Raasay and North-East Skye. By G. W. Lee, D.Sc., with contributions and an Appendix by S. S. Buckman, F.G.S. 93 pp.; 10 plates, 1 text-figure. 1920. Price 6*s.* net.

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APPENDIX I.

The Banffshire Coast Section of the Highland Schists.

By H. H. Read.

It is fortunate for the study of the Highland schists of North-East Scotland that, in the Banffshire Coast Section (Sheet 96), there is available what is probably the most continuous section of these rocks in the Highlands. This section (Fig. 2) is over 25 miles in length, with but a few trifling gaps, all of which can be filled by adjacent inland exposures. Except at a few localities, the cliffs are easily accessible and, together with the rocky foreshore, provide magnificent sections for study. The run of the coast line is west and east, almost at right angles to the strike of the Highland schists—a circumstance showing once more the exceptional nature of this section. Upon its interpretation must depend the interpretation of the somewhat poorly exposed Buchan, Strathbogie and Lower Banffshire districts of the North-East Highlands.

No modern work has been done on this section. Amongst the early workers are numbered Jameson,[1] Prestwich,[2] Hay Cunningham,[3] Harkness,[4] and Wallace.[5] The ground was originally mapped by Dr. John Horne, and his results were published in 1895 as the present One-inch Sheet 96 (Banff) of the Geological Survey Map of Scotland.

The lithological sequence of the Highland Schists of the Banffshire coast section from west to east is as follows :—

Keith Division	(*a*) Cullen Quartzite { a^1—Findochty Beds. a^2—Logie Head Beds.
	(*b*) West Sands Garnetiferous Mica-Schist.
	(*c*) Findlater Flags.
	(*d*) Crathie Point Calcareous Group.
	(*e*) Garron Point Actinolitic Schists.
	(*f*) Sandend (Black Schist-Limestone) Group.
	(*g*) Durn Hill Quartzite.
	(*h*) Portsoy Group.
	(*j*) Cowhythe Gneiss.
Banff Division	(*k*) Boyne Limestone.
	(*l*) Whitehills Group.
	(*m*) Boyndie Bay Group.
	(*n*) Macduff Group.

[1] Robert Jameson, 'Mineralogy of the Scottish Isles,' vol. ii, 1800, pp. 267–279.

[2] J. Prestwich, 'On the Structure of the neighbourhood of Gamrie, Banffshire,' *Trans. Geol. Soc.*, vol. v, 1840, p. 141.

[3] J. H. Cunningham, 'Geognostical Account of Banffshire,' *Trans. High. Agric. Soc., Scot.*, vol. xiv, 1843, pp. 447–502.

[4] R. Harkness, 'On the Metamorphic Rocks of the Banffshire Coast,' *Quart. Journ. Geol. Soc.*, vol. xviii, 1862, pp. 331–336.

[5] T. D. Wallace, 'The Geology of Rathven and the Enzie,' *Trans. Edin. Geol. Soc.*, vol. iii, 1880, p. 331.

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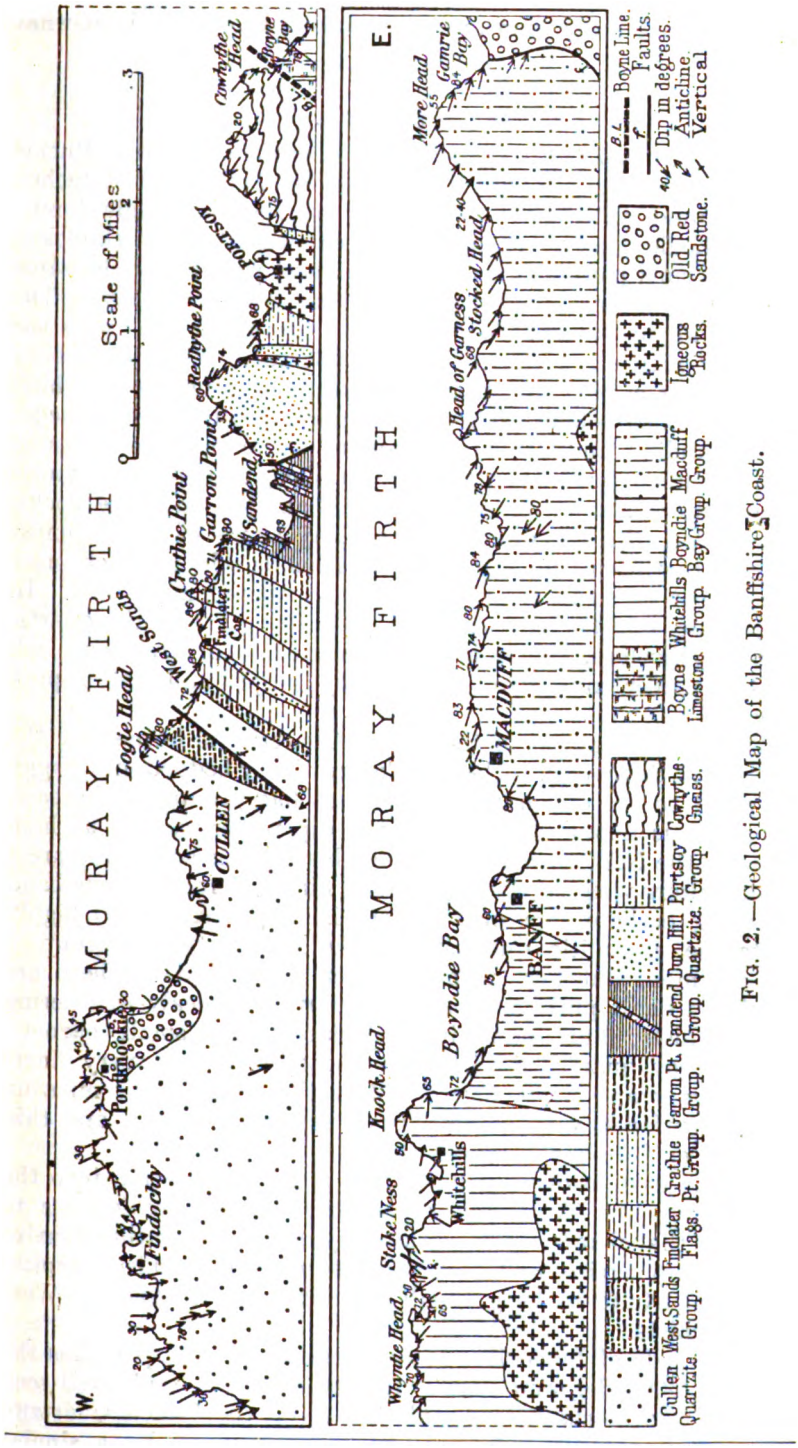

FIG. 2.—Geological Map of the Banffshire Coast.

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A short description of these groups will be given, and the reasons for the separation into two divisions developed, in what follows.

KEITH DIVISION.

(a) *Cullen Quartzite.*—This group forms the coast from Buckie eastwards to Logie Head, 1 mile east of Cullen. A detached area is found, with a breadth of 500 yds., at Sunnyside ¼ mile east of Logie Head. From Buckie eastwards to Portknockie, the coast runs parallel with the strike, and practically the same beds—the *Findochty Sub-group*, are seen all the way. The strike is about E.N.E.—W.S.W.; the prevailing dip is to the S.S.E., at rather low angles. The staple rock of the Findochty Sub-group is a very fine-grained granulitic quartzite of a white, grey or pinkish colour. The rock is massive and in thick beds; colour banding and the production of white mica in zones of intense folding have been noted. In slice, orthoclase is found to be almost always present in small amount in these rocks. Interbedded with the quartzite are many bands of dark, almost black, garnetiferous mica-schist; such bands seldom reach more than a foot or so in thickness, and are usually much less. In slice, these schists are composed of coarse, granulitic quartz, scarce orthoclase, abundant yellow-green to greenish-black biotite, scarcer muscovite and spongy porphyroblasts of pink garnet.

The remaining part of the Cullen Quartzite is formed by the *Logie Head Sub-group*. These rocks are thinly bedded and flaggy and point to the oncoming of the great flag groups to the east. The strike is about N.E.—S.W., the dip is vertical, or at high angles to the N.W. or S.E. The members of this sub-group are a rapidly alternating series of different kinds of rocks, each band averaging perhaps one or two feet in thickness. The highly crystalline granulitic quartzite of the Findochty Sub-group is still common, but here forms thinner bands. With these are associated dark, pinkish micaceous quartzites, mealy-weathering quartz-schists, buff quartzites speckled with small garnets, banded grey quartzites with thin micaceous layers, very finely banded grey and white flaggy beds with much silvery mica on the flag surfaces, very garnetiferous dark mica-schists, and thin bands of epidote-hornblende-granulite.

At the east head of Logie Head, a good transition into the next group—the West Sands garnetiferous mica-schists—is to be seen, the change taking place by the interstratification of granulitic quartzites and dark garnetiferous mica-schists, typical Cullen Quartzite rocks gradually giving place to typical West Sands schists.

Eastwards of Logie Head, the West Sands Group makes the coast for 500 yds., and then is faulted out by a fault well seen between tide marks. This fault brings on the Cullen Quartzite again for about 500 yds. until these rocks pass, by a similar

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transition phase, eastwards into the main outcrop of the West Sands Group at West Sands.

(b) *West Sands Garnetiferous Mica-Schist.*—At West Sands this group has an outcrop 120 yds. wide, with a high dip to the S.E. The group also forms the shore section for 500 yds. between the two outcrops of Cullen Quartzite, as already mentioned. In both places a gradual passage from Cullen Quartzite is seen; eastwards from West Sands, the West Sands Group passes gradually into the Findlater Flags. In West Sands, the staple rock of the group is a dark garnetiferous mica-schist, with quartzose bands and quartz kernels. In the centre of the outcrop there is a *calcareous* zone made up of thin, siliceous limestone bands, aggregating in all perhaps 2 or 3 ft. in thickness. In slice, the staple garnetiferous mica-schist is composed of two micas, quartz and garnet. The garnet forms porphyroblasts usually better shaped in the finer grained rocks.

(c) *The Findlater Flags.*—This group follows evenly eastwards from the West Sands Group and, by the incoming of calcareous material, it passes evenly into the Crathie Point Calcareous Group on its eastern margin. It forms the shore section for about 1,000 yds.; dips are high, usually to the S.E., but occasionally to the N.W. Throughout its outcrop, this group is composed of grey quartzose beds separated into flags by the development of mica on plane surfaces. Usually individual flags are about an inch or so in thickness. In slice, the typical flags are seen to be plane-foliated micaceous granulites composed of quartz and parallel plates of biotite and muscovite; the muscovite is occasionally set in large plates athwart the foliation. Garnet is seen in many slices. At Findlater Castle there is a narrow band of white, highly crystalline pure quartzite which, in slice, is seen to be composed of large sutured grains of quartz, with a very small quantity of white scaly mica.

(d) *The Crathie Point Calcareous Group.*—This group follows eastwards from the Findlater Flags, and forms the coast section between Crathie Point and Garron Point. Its width across the strike is about 570 yds.; dips are usually over 80°, and are predominantly towards the west. The main rock of the group is a pale, calcareous mica-schist, often weathering with a honeycombed yellow crust. In slice, this rock is a calc-biotite-schist, composed of about 75 per cent. calcite together with biotite, and quite subordinate quartz grains. With this calcareous flag type there are associated a few bands of very coarse, quartz-kernelled, kyanite-biotite-gneiss. Thin bands of garnet-staurolite-schist are also encountered. Towards its eastern margin, this group contains a few bands of actinolite-schist, which becomes the dominant rock in the succeeding Garron Point Group.

(e) *Garron Point Actinolitic Schists.*—This group follows evenly from the Crathie Point Group, and passes eastwards into the Sandend Group, in which rock-types characteristic of the Garron

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Point Group still persist. The width of the outcrop across strike is about 330 yds. The general dip is between 70° and 80°, and is either to the S.E. or N.W. The characteristic rock of this group is a dark, lustrous, poorly schistose rock in which there is a great development of blades of dark actinolite in felted masses, aggregates, or subradiate groupings.

Similar rocks occur at the eastern margin of the Crathie Point Group and throughout the Sandend Group, and show the essential unity of this part of the Keith Division. The actinolite-schists, unquestionably of sedimentary origin, represent the effect of regional metamorphism on an impure calcareous rock. In slice, they are composed of quartz, biotite and calcite as a ground-web, in which are set large porphyroblasts of pale green or almost colourless actinolite. With the actinolite-schists are associated flaggy micaceous quartzites and lustrous fine-grained dark grey schists with moiré surfaces.

(f) *The Sandend (Black Schist-Limestone) Group.*—This group is one of the most important stratigraphical divisions of the Highland Schists of this section. Its main rock types are black schist and limestone; stratigraphical groups characterised by these two rock types are known throughout the Highlands. On the coast the Sandend Group forms the shores of Sandend Bay and follows evenly from the Garron Point Group, but is faulted against the succeeding group on the east, that of the Durn Hill Quartzite. This fault runs N.W.–S.E., and a short distance inland what may be taken to be the full succession of the Sandend Group is found. The width of the fullest outcrop across strike is a little more than a mile; the dip is uniformly S.E. at angles of 66° to 80°. In the fullest succession there are seven broad belts of limestone, but whether these are distinct limestones or repetitions of one or more is not yet settled. A summary of the succession from the margin of the Garron Point Group eastwards is as follows :—(i) crushed good black schist with white limestone lenticles, 5 yds.; (ii) thick limestone, 17 yds.; (iii) calcareous flags, black schists, actinolite-schists and mica-schists, 170 yds.; (iv) limestone, 17 yds.; [gap of 365 yds.]; (v) limestone, 40 yds.; (vi) black schist, 230 yds.; (vii) limestone, 60 yds.; (viii) black schist, 22 yds.; (ix) limestone, 120 yds.; (x) black schist, 2 yds.; (xi) limestone, 90 yds., faulted against Durn Hill Quartzite. To this section may be added, from inland exposures in the Burn of Fordyce, the following items :—(xii) black schist with staurolite, 372 yds.; (xiii) limestone, 150 yds.; (xiv) black schist with staurolite, 230 yds., up to the approximate edge of the Durn Hill Quartzite.

(g) *Durn Hill Quartzite.*—This group takes its name from Durn Hill, 2 miles S.W. of Portsoy; it occurs on the coast at Redhythe Point between Sandend and Portsoy. The width of its coastal outcrop across strike is perhaps a mile; dips are steep and variable; the strike varies between N.E.–S.W. and N.–S. The group is faulted, on the coast, against the Sandend Group

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as has already been pointed out, but eastwards it passes into the Portsoy Group. Inland, this quartzite is at present considered to be conformable to its neighbours. The rocks of this group are more impure, more massive, less flaggy and less alternating than those forming the Cullen Quartzite already described. The most quartzose type is a felspathic quartzite composed of quartz, orthoclase, acid plagioclase and microcline, and micas. With this type are associated mica-quartz-gneisses, sillimanite-gneisses, flaggy micaceous quartzites and garnetiferous mica-schists, the last three rocks being of restricted occurrence.

(h) *Portsoy Group.*—This group occurs on both sides of Portsoy and follows on eastwards from the Durn Hill Quartzite. Its outcrop is about one mile across strike, but over half of this breadth is occupied by the sill-like mass of Older Igneous Rocks comprising serpentinised pyroxenite and peridotite, anorthosite, gabbro, enstatite-gabbro, epidiorite, amphibolite, gabbro-schist, hornblende-schist and hornblende-granulite, of which a summary has been given elsewhere.[1]

The sediments of the Portsoy Group are varied. A traverse eastwards from the east edge of the Durn Hill Quartzite shows the following succession. For 400 yds. the rocks are dark corrugated mica-schists, often silvery and garnetiferous : in this series are three narrow zones of graphite-schist. The dip hereabouts is E.S.E. or S.E. at 50°–70°. Eastwards of this belt and occupying the shore for over 100 yds. there is a very varied, rapidly alternating, group of banded calcareous flags and abundant tremolite-limestones, followed by chiastolite-staurolite-schist, dark calcareous flags, limestones and quartzose calcareous flags till the western edge of the igneous rocks is reached. Amphibolite and serpentine now form the shore for over 100 yds. Then, for about another 100 yds., a varied series of sugary white quartzite, dark mica-schist, white calcareous flags and white limestone is found before the western edge of the main mass of igneous rocks is reached. The igneous rocks form the coast about Portsoy Harbour, and include blocks of wollastonite-rock in them. The sediments, where next seen on the east shore of Links Bay, are crumpled and corrugated limy flags, impure limestones and dark mica-schists which soon pass eastwards into the next group, the Cowhythe Gneiss.

Superficially the Portsoy Group is like the Sandend Group, but when the two groups are mapped in detail, it is seen that there is really very little similarity between them.

(j) *Cowhythe Gneiss.*—This well-marked group forms the coast from Links Bay eastwards almost to the Boyne Burn. Across strike its width is a little over a mile. It follows evenly eastwards from the Portsoy Group, but is separated from the first member of the Banff Division, namely, the Boyne Limestone, by a line of

[1] H. H. Read, *Geol. Mag.*, 1919, p. 364; 'Summary of Progress for 1918' (*Mem. Geol. Surv.*), 1919, p. 26.

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disruption which may be called the *Boyne Line*. Throughout its extent the Cowhythe Gneiss is a dark, gnarled coarse biotite-gneiss with subordinate finer mica-schist bands; throughout kernels, stringers and bands of quartz are very common. In slice, the typical gneiss is composed of quartz, acid plagioclase, biotite and muscovite, occasionally with sillimanite, cordierite and tourmaline. At a point 300 yds. from its western edge, there is a calcareous horizon with about 10 ft. of white limestone, which may be called the Rosehall Croft Limestone. At the Boyne Line, the Boyne Limestone is composed of thin limestone and purplish phyllites. As these rocks are followed in towards the margin of a nose of good Cowhythe Gneiss, they are seen to be drawn out and finally to disappear against the gneiss. All around there is much brecciation and slickensiding of the rocks. A short account of the phenomena along the Boyne Line as it is traced inland will be given in a later page.

Banff Division.

(k) *Boyne Limestone.*—Eastwards of the Boyne Line, the Boyne Limestone is seen around Craig of Boyne and Boyne Bay. From the Boyne Line eastwards for perhaps 140 yds., the rocks are thin limestones, purple phyllites and banded mica-schists with quartz kernels. Several fault breccias are seen hereabouts. Eastwards follows the thick mass of Boyne Limestone, which has a width across strike of about 300 yds. This limestone is grey, blue or white, with thin intercalations of more impure material and with nests and kernels of quartz. It is violently folded and crumpled.

(l) *Whitehills Group.*—The Boyne Limestone passes eastward into this group by the incoming of purplish phyllites and the gradual disappearance of limy bands. The Whitehills Group forms the coast for three miles, and is linked on the west to the Boyne Limestone and on the east to the Boyndie Bay Group. It is a very flaggy group made up of rapid alternations of its several members. These are banded flaggy quartzites, compact fine-grained limestones, coarse gritty limestones, calcareous flags, purplish phyllites and pebbly grits with large pebbles of quartz and pink felspar. In addition, there are a few bands of nodular andalusite-mica-schist, which become more common towards the east till the next group is reached, in which they are the predominant rock type. On the whole, it may be stated that the pebbly limestones are confined to the western and central parts of the outcrop, the coarse pebbly grits and andalusite-schists to the eastern part. On Knock Head, there is a great development of coarse pebbly grit with pebbles, occasionally composite, but more often of either quartz or pink felspar, which may reach an inch or more in diameter. Several broad sills of amphibolite are found in this group about Whyntie Head.

(m) *Boyndie Bay Group.*—This group is seen in Boyndie Bay to the west of Banff. Throughout it there occur bands of pebbly

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quartz-felspar-grit like those already mentioned from the preceding group. The main rock is, however, a slaty rock, characterised by the gradual development of andalusite from a rudimentary to a complete form. The western edge of the group is characterised by silvery rocks studded with large crystals of andalusite; these are followed eastwards by rocks with elongated knots of andalusite, and these, still further east, by spotted slates which, in turn, give place to the unspotted slates of the next group. Whatever the cause of this development of andalusite, it is apparent that its effects increase in intensity from east to west.

(n) *Macduff Group.*—This great group occupies the remainder of the coast section here described, and is well exposed for a distance of 9 miles eastwards from Banff. The beds are thrown into a rapid series of steep-sided folds; but, even so, this group is probably of very great thickness. Strikes are between E.N.E.–W.S.W. and N.E.–S.W. The main rock of the group is a blue or green slate which has been worked for roofing slate at various points. With this occur in subordinate amount, pebbly quartz-felspar-grits, fine-grained grey and white grits, and fine blue greywackes.

There can be no doubt that the four members of the Banff Division form a natural stratigraphical sequence; they are linked together by transitions and by a thorough community of rock types.

It has now been shown that the Highland schists of the Banffshire coast section fall into two great divisions, separated by the line of disruption described as the Boyne Line. To the west of the Boyne Line there is the Keith Division, composed of rock types which are probably the continuation of Central Highland rocks. The Keith Division is thoroughly metamorphic in character; schists and gneisses represent the pelitic facies of the original sediments; chief among the metamorphic minerals are garnet, staurolite, kyanite and sillimanite. Eastwards of the Boyne Line is the Banff Division of which a few types recall some of those of the Loch Awe district of the S.W. Highlands. This division is much less highly metamorphosed; phyllites, rather than mica-schists, predominate in the more highly-metamorphosed parts; slates and clastic sediments are widespread; andalusite is the characteristic metamorphic mineral of this division.

If the ideas of metamorphic zones conditioned by depth of burial, advanced by C. Van Hise, F. Becke, U. Grubenmann and others, are to be accepted, then it follows that the Banff Division is structurally above the Keith Division. Further, the Macduff slates must be structurally the highest member of the Banff Division.

The phenomena along what may be considered the inland extension of the Boyne Line are not without interest. The thick

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Boyne Limestone (the thickest limestone of this section) can be followed southwards for less than 2 miles. Southwards, again, the Cowhythe Gneiss is adjacent to the Whitehills Group. Still further south, both the Cowhythe Gneiss and the Whitehills Group vanish, and in the ground to the S.W. of Huntly the Portsoy Group comes against the pebbly grits and andalusite-schists of the Boyndie Bay Group. It seems possible, therefore, that this line of disruption that has been found at the Boyne on the coast may be an important tectonic feature in the architecture of the Highland Schists of N.E. Scotland. The complete elucidation of the Boyne Line can only be obtained by the detailed study of the Buchan, Formartine, Alford and Strathdon districts of Aberdeenshire—a study which has not yet been attempted.

The Banffshire Coast Section in relation to the Highland schists of other parts of Scotland.—The chief point of interest following from this study of the Banffshire rocks seems to be their separation into two divisions. There appears to be little doubt that one of these—the *Keith Division*—represents the northern continuation of the Perthshire Schists described by Mr. George Barrow, Mr. Cunningham Craig and others, in the Memoirs on Sheets 55, 65 and 64. There seem to be very large questions still to be settled in the Perthshire ground and, until some agreement has been reached as to the stratigraphical sequence in this area, it is a hazardous proceeding to attempt any thorough correlation.

It has been shown that, in Banffshire, there are two quartzites, of which one, the Cullen Quartzite, contains rock types in a Moine state. The Cullen Quartzite is undoubtedly that seen at Ben Aigan on Speyside (Sheet 85), and the Ben Aigan Quartzite appears to be continued south by a belt of quartzite at the edge of the Moines to Inchrory in Sheet 75. South of this, the cordon of the Cairngorm, Lochnagar and Hill of Fare Granites sweeps right across the path of the Keith Division. Two quartzites, so far as I know, have not been recognised in Perthshire. There is every reason to believe that the second Banffshire Quartzite, that of the Durn Hill, is the Central Highland Quartzite of Perthshire. I hold, at present, that the Durn Hill Quartzite is conformable to its neighbours and is interstratified in the Keith Division. The relations of the Central Highland Quartzite in Perthshire are the subject of dispute.

Another fairly sure step may be made. The Sandend (Black Schist-Limestone) Group, occurring on the west side of the Durn Hill Quartzite, appears to be equivalent to the Blair Atholl (Black Schist-Limestone) Group occurring on the west side of the Central Highland Quartzite. Lithologically they are the same.

The Findlater Flags, Crathie Point Group and Garron Point Group resemble the Parallel Banded Series (Hones) and Tremolite-

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Limestone of Perthshire, and it is possible that this correlation will hold.

It has been shown that, in Banffshire, the rocks on the opposite sides of the Durn Hill Quartzite are, while somewhat similar, two distinct rock groups, those of Sandend and Portsoy. From what can be made out of the complicated and, in part, controversial description of the Perthshire ground, it appears that this independence of the two 'dark schist and limestone' groups on opposite sides of the Central Highland Quartzite has not always been recognised. In agreement, I believe, with Mr. George Barrow, I am inclined to correlate, after a short visit to the Perthshire ground, the Portsoy Group with the zone of thin limestone and dark schist seen on the south-east side of the Central Highland Quartzite on Farragon Hill and Beinn Eagach, and beside the Tummel opposite Faskally House. In the published map of this ground (Sheet 55), this Beinn Eagach group is shown as running into the Blair Atholl group on Meall Uaine, north of Pitlochry. This, from my Banffshire experience, I consider to be extremely unlikely.

To the south-east of the Beinn Eagach Group of Perthshire, there occur the Ben Lawers Schists (= Calc-sericite of Central Perthshire = Caenlochan Schists of Forfarshire, *fide* Mr. G. Barrow). These are possibly represented in Banffshire by the Cowhythe Gneiss.

No representative of the Schichallion Boulder Bed has yet been found in Lower Banffshire. It is known in Upper Banffshire at Meikle Fergie Burn, opposite Gaulrig, south of Tomintoul.

The following table of quite tentative correlations may be constructed :—

Banffshire.	Perthshire.
—	Loch Tay Limestone
—	Garnetiferous Mica-Schist
Cowhythe Gneiss	Ben Lawers Schists
Portsoy Group	Beinn Eagach Group
Durn Hill Quartzite	Central Highland Quartzite
Sandend Group	Blair Atholl Group
Garron Point Group, Crathie Point Group	Tremolite-Limestone
Findlater Flags	Parallel Banded Rocks or Hones
West Sands Group	—
Cullen Quartzite	—

The *Banff Division*, with its great development of slates, pebbly grits and gritty limestones, appears to be absent in Perthshire; this division is probably confined to Lower Banffshire, Strathbogie, Cabrach, the Howe of Alford, and Buchan. A few of its rock types, notably the pebbly quartz-felspar-grits and the gritty limestones, are lithologically similar to types occurring in the Loch Awe region of the South-west Highlands. Further, the state of metamorphism is low in both areas. No

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definite correlation between the Banff Division and the Loch Awe Group is advanced here; the above suggestions, however, are to be borne in mind in any further investigation of the North-East Highlands. By the development of research in the South-West Highlands, it is possible that some light will be thrown on the problems of the Banff Division, and in particular with regard to the significance of the Boyne Line and the resemblances of this division to the Loch Awe Group.

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APPENDIX II.

Report on Sections exposed in Excavations for Sewers in the Parish of Brockenhurst, Hants.

By H. J. Osborne White, F.G.S.

1. Introduction.

The construction of the Brockenhurst Sewer-System was undertaken for the Lymington Rural District Council by Messrs. Grounds and Newton, Contractors, of Richmond Chambers, Bournemouth, according to plans prepared by Messrs. Shanton and Easdale, Engineers, of No. 28, Victoria Street, Westminster.

Begun at the lower, or Disposal-Sump, end in 1914, and discontinued during the late war, the work was resumed in the autumn of 1919, and completed, as far as excavation was concerned, by the end of December, 1920. (The full drainage-scheme includes connections with Setley, Brockenhurst Weirs, and other outlying or detached settlements, but the construction of these branches has not yet been sanctioned.)

At the request of the Director of the Geological Survey (Sir Aubrey Strahan), the author of this Report made a preliminary inspection of the ground within the area of the Sewer System on the 9th–10th July 1920, and subsequently revisited Brockenhurst on eleven occasions, between the latter date and the 1st January 1921, with the object of compiling a record, and collecting specimens, of the strata exposed in the sewer-trenches opened under the then-existing contracts with the District Council. Opportunity was taken to inspect a number of pits in the Headon Beds, near Brockenhurst, all of which were found to be in worse condition than they had been six or seven years before; and a visit was paid to parts of the Barton coast-section having a direct bearing on the stratigraphy of the Sewer area.

The writer is under an obligation to Mr. W. Faber Elliot, the Resident Engineer, for ready assistance in the examination of the Sewer works and plans, as well as for periodical communications relating to the progress of the trenching and the nature of the ground in course of excavation.

2. Geological and other Formations Exposed.

Barton Sand.—To judge by their lie and character, the oldest strata trenched belong to the uppermost 20 ft. of the Becton Bunny Beds, or middle stage of the Barton Sand, as developed in the cliffs of Christchurch Bay. They consist of evenly-bedded, fine-grained, ferrous, micaceous, muddy sands; of blue-grey tint in the deeper sections and in those below local stream-level;

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dark-yellow, orange, or brownish-red where weathered. Their junction with overlying permeable beds, whether of Barton or later age, is commonly marked by a band of orange coloration, which is fairly constant in width, as if pertaining to a definite stratum, where the cover is part of the Barton Series.

The succeeding Long Mead End Sands (about 15 ft. thick) also are fine-grained and micaceous, but contain much less argillaceous and ferruginous matter, and are normally loose and light-tinted; pale greys and yellows predominating. Near their upper limit, however, they become rather loamy and greenish-grey, owing to the introduction of green mud like that prevailing in the Lower Headon Beds above, and include thin seams of a more positively argillaceous nature. At the Sewage Disposal Works, by Haze Farm, a light-green loamy sand, inferred to lie immediately below the Headon Beds, contains marcasite-concretions; some of irregularly lenticular shape, following the lamination of the sand; others sub-cylindrical, and disposed at various angles thereto. The scanty and ill-preserved organic remains observed in the Barton Sand of the Sewer area occurred as casts (wood, *Cyrena sp.*, *Psammotea* ?) in the lenticular concretions.

Lower Headon Beds.—The lateral variation to which the members of this freshwater series are subject was apparent in the Brockenhurst trenches.

The well-marked bottom-bed, which rests evenly on the Barton Sand, normally consists of a few inches of black, dark-grey, or soot-coloured carbonaceous silty clay to loam; partly laminate or shaly; partly (where the silt element predominates) of confused, flocculate structure. When weathered, it assumes the colour and appearance of moulded chocolate, and, in the majority of the trench-exposures, this facies only was presented. In at least two sections of the Headon-Barton contact, in the southern part of the Sewer area, the bed in question was missing.

In the neighbourhood of the Railway Station, the bottom-bed is succeeded by a white to pale greyish and greenish clayey silt, mottled rusty-brown, and resembling marl, but free from calcium carbonate. Similar deposits occur at the same horizon at and about the Disposal Works, half a mile to the north-east, and at Lymington, 4 miles to the south. In the southern part of the Sewer area, however, a bright-green clay with red mottling takes the place of the pale silt, which is either absent from the lower portion of the Headon succession, or—as in one observed instance—is developed at a slightly higher horizon.

Next follows light-green to greyish-green tough clay; pure, or with silty inclusions, in the lower part, and becoming arenaceous upward through the introduction of fine white quartz-sand, which occurs chiefly in little nests and thin partings. The succeeding beds of this Series, as far as seen, are light-greenish and greyish distinctly-sandy clays and clayey-sands.

No fossils could be found, either in the trenches or on the rain-washed heaps of excavated material. Save for a little

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granular race, the visible parts of the beds had been decalcified. The maximum thickness of Headon Beds exposed was about 20 ft. It was hoped that the interesting basal ('Brockenhurst') beds of the Middle Headon, which approach to within that number of feet of the Barton Sand under Ladycross Lodge, 2 miles eastward, would be encountered in the trenches near the Railway, but nothing resembling them, or suggesting deposition under marine conditions, was forthcoming.

Valley Gravel.—The bulk of this is typical river-gravel, of fine to medium texture, sandy, clearly stratified and current-bedded. Approximately 99 per cent. of the stones are sub-angular flints; the residue is made up of flint pebbles, sub-angular Selbornian cherty sandstone, pebbles of vein-quartz, &c., all most probably derived from the Plateau Gravel of the basin of Lymington River. The sand mingled with the stones, and occurring separately in seams and lenticular banks intercalated in the gravel, is mostly of light tints, and resembles that of the highest beds of the Barton Sand. In places, beds of reconstructed dark bluish-grey (Becton Bunny) sand were met with, one of which (at Waters Green) contains remains of plants. Masses of green clay and pale silt detached from the Headon Beds are not uncommon near the boundary of that formation. Cementation of the gravel, by iron peroxide and calcareous tufa, occurs sporadically and on a small scale. The greater part of the Valley Gravel within the Sewer area is disposed in gently-inclined sheets, rising from beneath the Recent Alluvium to a height of about 20 ft. above the neighbouring streams.

Trail.—In many places the Tertiary formations and the Valley Gravel are covered by from 1 to 5 ft. of stony or gravelly loam and sandy clay, largely composed, and containing incompletely assimilated bodies, of Headon clay and sand, Barton sand, and Plateau or Valley gravel; and commonly possessing a rude flow-structure, which was well displayed in the wet, clean-cut sides of the sewer-trenches. The bottom of the deposit is markedly uneven, especially on sand and gravel, into which it descends in vertical and oblique pockets. While this pocketing —and the contortion-phenomena often associated with it—may be due in a great measure to repeated intrusion, expansion and decay of tree-roots under present-day conditions, the trail itself is most probably the outcome of exceptionally active solifluction, under bygone conditions inimical to forest vegetation.

By the progressive blending of its varied constituents, the trail passes into impure brickearth. About Brockenhurst the trail is of no little importance agriculturally, inasmuch as it masks a good deal of stiff Headon clay, and affords a retentive soil for grass and arable-land over tracts of normally barren sand and gravel.

Alluvium.—This comprises peat, sandy flood-loam (brown and of open texture near the surface; greyish and more compact below), and parts of the low-level Valley Gravel rearranged by

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the streams in Recent times. Thin peat and peaty earth or sand, occupying slight hollows in the flood-loam and Valley Gravel, were intersected by the trenches at Culverley Green and south-west of Brockenhurst Bridge. In the first-named locality, sand and gravel, containing much peaty matter and drift-wood were met with a few feet beneath the bed of the brook.

Made Ground.—Except in the railway-embankments and causeways, and above culverts and water-mains, the made ground cut by the sewer-trenches was of moderate or trifling thickness, and generally consisted of road-metalling. The writer neither saw, nor could hear of the discovery of, any objects of archaeological interest. The early settlement of Brockenhurst presumably lay on the spur of comparatively high ground supporting the Parish Church, outside the area of the sewer-system.

3. Rectification of the Geological Survey Map.

The boundaries of the Solid formations and of the Valley Gravel about Brockenhurst are so obscured as to render their accurate mapping impossible, without the aid of the boring-tool, or of an adventitious series of cross-sections, such as those afforded by the main-drainage works.

At Balmer Lawn, the boundary of the Headon Beds lies a little to the west of the line assigned to it in the current Geological Survey Map on the 1-in. and 6-in. scales; while in the tract between the grounds of Careys (formerly 'Brockenhurst Lodge') and Brockenhurst Weirs, it lies in places nearly half a mile south-east of that line. In the latter area, a thin spread of trail is responsible for the misleading occurrence of soils and vegetation appropriate to the Headon Beds on a low-lying portion of the Barton Sand outcrop. The Headon Beds hereabouts come on in a slight rise, which begins to be noticeable some 150 to 200 yds. north-west of, and 10 to 15 ft. below, their boundary.

The Valley Gravel proves to extend farther southward of the Lymington River than has been supposed, and to occur in considerable thickness within a few yards of its southern limit near the middle of the village. Boundary features are faint or wanting, much of the ground having been smoothly graded before and during the formation of the trail.

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APPENDIX III.

On Borings for Coal near Maryport, Cumberland.

By Bernard Smith, M.A.

Two boreholes have been put down recently, by the Cumberland Coal, Power and Chemicals, Ltd., to test the Coal Measures concealed beneath the New Red Sandstone near Maryport, on the northern side of the so-called 'Boundary Fault' of the Cumberland coalfield.

Near Maryport, at least, it was expected that higher Coal Measures would have been present than in the exposed field south of the fault; in fact, the Boundary Fault had previously been driven through in the Ten Quarters Coal at Ellenborough Colliery,[1] and Whitehaven Sandstone was said to have been entered on the north side, and to prove a great downthrow in that direction, corresponding with the downthrow observed in the Triassic Rocks.

The strata penetrated by these bores, however, did not support this view, and, moreover, did not appear to correlate with anything known in this part of the county. At the invitation of the Company the cores were first examined in detail in May 1920, and permission to publish the results has been given freely by Messrs. A. E. Barton and H. E. P. Cottrell, Directors of the Company. Our thanks are also due to Major J. G. Scoular of Oughterside Colliery, under whose supervision the borings were made.

Bank End Boring (Fig. 3).

This boring is situated close to the cemetery, 1½ miles N.N.E. of Maryport, on the west side of the road to the coast. One-in. New Series Ordnance Map, Sheet 22; Old Series Geological, 101 N.W.; 6-in. Cumb. 45 N.W. Lat. 54° 43′ 55″, Long. 3° 28′ 25″. Height of surface above O.D. 27 feet.

The boring was executed by the Sullivan Machinery Co., U.S.A. Commenced November 1919 and completed May 1920. The cores were 2-in. diam. throughout. The dip in the St. Bees Sandstone is low; in the Coal Measures it varies from about 10° to 18°, and in the Carboniferous Limestone Series from 13° in shales (1,826 ft.) to as much as 30° or 35° (1,707 ft.) in laminated sandstones.

The journal of the boring is printed in slightly condensed form as it was received from the engineers, but descriptive notes, in square brackets, have been added after examination of the cores.

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[1] 'Final Report of Royal Commission on Coal Supplies,' 1905, pt. ix., p. 17.

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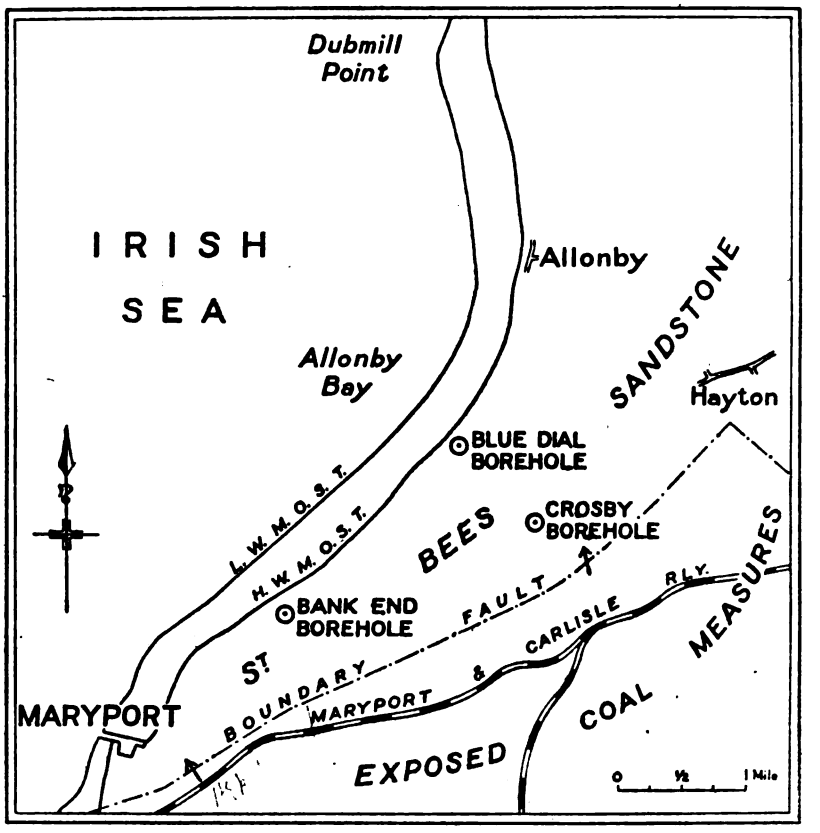

FIG. 3.—Sites of Borings near Maryport.

	Thickness. Ft.	in.	Depth. Ft.	in.
GLACIAL :—				
Gravel, clay and sandy clay	34	0	34	0
ST. BEES SANDSTONE :—				
Red sandstone, with bands of red marl and shale: thin bands of gypsum between 283 and 493 ft. [sandstones with greenish-grey bands at intervals: the chocolate-red shales are micaceous in places]	510	6	544	6
[Breccia] Base of sandstone with small marl pebbles, &c.; Red and green marls churned together; Fragments of Coal Measure shales, &c.	3	0	547	6
LOWER COAL MEASURES :—				
Rough red shale, variegated [purplish fine-grained shales and sandstones, with occasional concretions of hæmatite]	23	8	571	2
Very dark shale		4	571	6
BONE COAL [sandstone and coal mixed]	1	7	573	1
Grey sandy shale [with rootlets in upper part, on shales with ironstone balls]	10	11	584	0
Dark shale and metal [grey mud-stones with rootlets]	3	3	587	3

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	Thickness. Ft.	in.	Depth. Ft.	in.
Coal [poor and pyritous]		7	587	10
Hard grey shale	2	2	590	0
Sandy shale	6	0	596	0
Blue metal [grey and blackish mudstone with rootlets, pinnules and shells. Ironstone at 600 ft. 1 in.]	11	0	607	0
Red and dark shale, mixed	2	0	609	0
Red and grey shale [micaceous sandstone at base: spar joints]	5	0	614	0
Red sandy shale	6	0	620	0
Dark grey shale [mudstone with rootlets]	6	0	626	0
Very dark shale [with rootlets and shells]	11	5	637	5
Bone Coal with spar [and copper-pyrites]	1	1	638	6
Hard fireclay [mudstone with rootlets]	4	6	643	0
Fireclay [fine-grained, dark grey sandstone]	1	0	644	0
Grey beds and mixed sandy shale [red and black]	23	0	667	0
Light-brown sandstone [pinkish: micaceous near base]	39	0	706	0
Dark shale with variegated sandstone bands [dark and red sandy shales, both with black mica]	13	0	719	0
Dark shale [plants and shells]	2	5	721	5
Bone Coal	1	1	722	6
Fireclay [fireclay 2 ft., on sandy shale and sandstone]	7	6	730	0
Grey sandstone	3	0	733	0
Dark shale [with plants, shells and ironstone]	24	0	757	0
Black metal [smooth black shales with fossils]	1	11	758	11
Coal [poor]	2	3	761	2
Fireclay [and sandstone]	1	10	763	0
Sandy grey shale [chiefly white sandstone]	5	0	768	0
Dark shales, with ironstone [fossils]	9	3	777	3
Coal, traces of spar and sulphur [pyrites]	1	6	778	9
Fireclay	1	3	780	0
Dark grey shale [some fireclay]	18	0	798	0
Dark shale [shale and sandstone: plants]	24	4	822	4
Coal [with 3-in. roof of black shale]		11	823	3
Fireclay	2	9	826	0
Dark shales [and shaly sandstone]		10	826	10
Coal		1	826	11
Fireclay [brown and sandy]	2	1	829	0
Dark shale and grey bed [with current-bedded sandstones, and plants]	30	0	859	0
White sandstone on dark shale [plants]	10	0	869	0
Fireclay with ironstone bands near base	4	6	873	6
Grey sandstone	25	9	899	3
Dark shale [black: ironstone balls, and fish remains]	9	3	908	6
Fireclay [pulped shale on black shale]	2	0	910	6
Coal [poor]	1	9	912	3
Fireclay	2	9	915	0
Sandy shale	16	0	931	0
Fireclay [grey shale, on 18 in. fireclay]	5	0	936	0
Sandy shale and grey bed [1 ft. fireclay: plants]	15	0	951	0
Sandy and dark shales [soft black and micaceous: shells and plants]	25	10	976	10
Coal [core missing]		5	977	3
Dark shale [plants and ironstone]	6	9	984	0

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	Thickness. Ft.	in.	Depth. Ft.	in.
Coal [poor, with calcite joints]		8	984	8
Fireclay	1	4	986	0
Dark shales [mudstone with ironstone]	5	2	991	2
Coal [poor]		11	992	1
Fireclay	1	11	994	0
White sandstone	27	0	1,021	0
Fireclay and dark shale	5	0	1,026	0
Carboniferous Limestone Series :—				
Dark shales with shells and spar bands [crinoids and marine shells]	1	0	1,027	0
Sandy shales [white sandstone with dark shale and coaly layers]	4	0	1,031	0
Dark shales	1	0	1,032	0
Hard fireclay [shaly at top]	5	0	1,037	0
Fireclay [greenish shale]	3	0	1,040	0
Dark shale [shales and mudstones; ferrous carbonate and pyrites]	10	0	1,050	0
Dark shale	10	0	1,060	0
Dark brown shale [fossiliferous]	9	0	1,069	0
Grey bed, hard post and sandstone [whitish quartzose sandstone, with black mica, and 1 foot shale]	36	0	1,105	0
Dark shale with ironstone nodules and few shells	4	0	1,109	0
Hard dark shale [fossiliferous]	16	0	1,125	0
Dark firelay [smooth micaceous shale and bastard cannel]		8	1,125	8
Coal, very dirty [full of calcite]		4	1,126	0
Fireclay	1	6	1,127	6
Very coarse grey bed [sandstone and shales]	18	6	1,146	0
Dark shale with ironstone, pyrites and crinoids, on sandstone and shale : limestone at 1,171 ft.]	30	0	1,176	0
Sandstones and sandy shales [fossiliferous]	139	0	1,315	0
Red sandstone [pink, purple and white : micaceous]	13	0	1,328	0
Fireclay [dark grey, black and purple : micaceous]	2	0	1,330	0
Grey bed [20 ft.], on sandstone	48	0	1,378	0
Dark grey sandy shales [black mica and plants]	4	0	1,382	0
Grey bed, separated by sandstone, 4 ft. [plants]	23	6	1,405	6
Black shale [shells and plants]	12	0	1,417	6
Hard dark shales [dull sandy shales, calcareous in places : highly fossiliferous. *Reddish limestone* at 1,425 feet]	44	0	1,461	6
Red, on white, sandstone [white, pink and red, micaceous and with shales]	16	6	1,478	0
Black shale [mixed with sandstone : plants]	12	0	1,490	0
Dark black, sometimes sandy, shales and grey bed [pyrites nodules and traces of plants]	35	0	1,525	0
White sandstone [purplish in places : coaly layers]	13	9	1,538	9
Dark shale with 1 in. Coal		3	1,539	0
Grey bed and white sandstone, mixed	17	9	1,556	9
Coal		6	1,557	3
Brown shale		3	1,557	6
Fireclay [black, with rootlets]	3	0	1,560	6
Sandstone and grey bed	16	6	1,577	0
Dark shales, grey beds and sandy shales [plants, crinoids and shells from 1,636–1,637 ft.]	79	0	1,656	0
White sandstone	12	0	1,668	0
Dark shale and grey bed	27	6	1,695	6
Broken dark shale [1,697–1,698 ft., dark shale on black shale with *Lingula*]	3	6	1,699	0

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	Thickness.		Depth.	
Coal—*continued.*	Ft.	in.	Ft.	in.
Sandstones and grey beds, some red	37	0	1,736	0
Grey bed and dark shales	65	0	1,801	0
Sandstones, grey beds and shales [fossils at 1,826–7 ft.]	96	0	1,897	0
Grey and white sandstone	24	6	1,921	6
Dark shale [with sandstone: fossils at 1,954 ft. 6 in. in ferrous carbonate]	63	6	1,985	0
Grey bed, sandstone and shale with spar	14	0	1,999	0
Dark shales and sandstones, mixed	75	0	2,074	0
White sandstones and grey beds	157	0	2,231	0
Coal		4	2,231	4
Shale, sandstone and grey bed	64	8	2,296	0
Coal		4	2,296	4
Dark shale, grey beds, sandstones and shales	250	8	2,547	0
Coal		3	2,547	3
Shale and sandstone	36	3	2,583	6
Coal, small pieces	1	10	2,585	4
Sandstone, grey bed and shale	62	8	2,648	0

Blue Dial Boring (Fig. 3).

This boring is, in its essentials, similar to the above, but was finished at a slightly later date. It is situated close to the coast-line nearly 2 miles N.E. of the Bank End boring and about 200 yds. S.W. of Blue Dial. Six-in. Cumb. 35 S.W. Lat. 54° 45′ 9″, Long. 3° 26′ 25″.

Height of surface above O.D. 21 ft.

The dip of the lower series is in places as high as 30°.

A summary of the chief divisions is as follows:—

	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Glacial	46	6	46	6
St. Bees Sandstone, with 3-in. breccia at base	664	6	711	0
Lower Coal Measures, stained red and purple to about 880 ft., with 13 thin coals	951	0	1,662	0
Carboniferous Limestone Series, with coal and shale parting at from 2,043 ft. 8 in. to 2,045 ft. 8 in.	673	0	2,335	0

The breccia at the base of the Trias in this boring consisted of small pellets of New Red Marl and Sandstone in sandstone, on small fragments of Coal Measure shales. There was also a thin layer of fibrous gypsum close above the breccia. The junction was difficult to detect owing to the staining of the underlying Coal Measures.

The base of the Coal Measures in each boring has been fixed at a point below which there is the first appearance of crinoidal and shell-bearing shales of marine type. Lithologically, however, apart from some thin bands of limestone, calcareous shales, or calcareous sandstone, the lower series bears a resemblance to the Coal Measures. Bands and balls of ferrous carbonate and pyrites occur in both, and certain shales and sandstones contain black mica. Plant remains also occur in both. There is no sign of unconformity at the junction in either section.

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The 'grey-beds' are usually alternations or admixtures of sandstone and shale.

The Coal Measures contain no coals that can be recognised in neighbouring collieries and none appears to be of value. The coals in the underlying beds are apparently placed for the first time at their proper horizon, although they may have been bored through or may crop out in the district.

The fossils given below have been examined and named by Mr. J. Pringle and Dr. Robert Kidston, F.R.S.

LIST OF FOSSILS FROM BANK END BOREHOLE, MARYPORT, CUMBERLAND (B.S. 1439–1803).

	Depth in Feet.
Mariopteris muricata (*Schloth.*)	802–807
Neuropteris heterophylla *Brongn.*	735–744
,, *cf.* ,,	566, 570
,, tenuifolia (*Schloth.*)	818–820
,, *cf.* ,,	802–807
,, sp.	802–807, 818–820
Sphenopteris *cf.* obtusiloba *Brongn.*	802–807
Calamites sp.	735–744
Cf. Calamites carinatus *Sternb.*	,,
Asterophyllites charaeformis (*Sternb.*)	783
,, equisetiformis (*Schloth.*)	802–807, 818–82
Calamostachys sp.	818–820
Lepidophyllum sp.	958
Stigmaria ficoides (*Sternb.*)	980
Cordaites sp.	818–820
[1]Carbonicola *cf.* aquilina (*J. de C. Sow.*)	600, 630
[1] ,, sp.	571, 600–607, 631, 744–7
[1] ,, ?	744–747, 901
Crinoidal columnals	1,048, 1,068, 1,171
Fenestellid	1,062
Lingula squamiformis *Phill.*	1,697
,, *cf.* ,,	1,173
,, sp.	1,100
,, ?	977
Orbiculoidea nitida (*Phill.*)	1,428
Productus, *cf.* longispinus *J. Sow.*	1,425
,, sp.	1,425, 1,440
,, ?	1,280, 1,412
Schellwienella sp.	1,425
Cypricardella sp.	1,280
Euphemus urei ? *Flem.*	1,045
Coelacanthus sp.	571
Rhizodopsis sauroides *Will.*	571, 904
,, ,, ?	953–955
,, ?	632
Fish remains, indet.	906

[1] Freshwater shells.

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Mr. Pringle states that 'the marine shells which characterise the rocks passed through between the depths of 1,045 ft. and 1,697 ft., suggest comparison of the beds with the Cefn-y-Fedw Series of Denbighshire.' The latter has been shown in recent years to belong to the Carboniferous Limestone Series. Previously it had been termed 'Millstone Grit.'

The absence in these records of the 'Millstone Grit' of the Whitehaven District, and the extraordinary difference between the Carboniferous Limestone Series in the borings, which is of northern aspect, and that developed in the above district, where by far the greater part is massive limestone, are points of great interest and of economic importance, the significance of which will be better appreciated when the systematic mapping of the area is taken in hand and the various changes followed in detail.

That these changes have taken place before the Boundary Fault is reached from the south is proved by a boring recently sunk by the same Company at Hayborough, about 1 mile east of Ellenborough, in which strata of the Upper Carboniferous Limestone types met with at Bank End and Blue Dial crop out beneath the Glacial beds. Again strata of this lithological character, containing a thin limestone with *Schellwienella*, are exposed in two dingles ½ mile S.E. of Rosegill, and about 3½ miles east of Maryport.

A further point of interest is that the borings tend to prove that there must have been a downthrow (or steep turn-over) south-eastward along, or near the line of, the Boundary Fault, before the date of the Triassic overlap and the later northward downthrow. The supposed Whitehaven Sandstone met with in the above-mentioned driving through the fault, from the Ten Quarters Coal at Ellenborough, may well have been some of the sandstones of the Lower Coal Measures or Upper Limestone Series coloured by Triassic infiltrations.

The Crosby borehole[1] (Fig. 3) appears to have proved a sequence similar to that of the two borings under consideration, but in the absence of fossil evidence it is impossible to say exactly at what depth the Carboniferous Limestone Series was first reached—probably at much shallower depth than 1,046 ft. 9 in. which marks the top of a 33 ft. 3 in. bed of limestone. It appears, therefore, that, in the absence of faults, the base of the Coal Measures of this area strikes more or less parallel to the Boundary Fault and may dip seawards at something like 1,300 ft. per mile—an average dip of from 13° to 14°, which corresponds fairly well with the actual dips observed in the cores. The generally higher dip in the lower series is suggestive of unconformity.

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[1] *Ibid.*

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APPENDIX IV.

On a Boring for Coal at Yate, Gloucestershire.

By J. Pringle.

This borehole is situated in a field on the north side of the Bristol road 400 yds. west of Yate Station,[1] at a surface level of 225 ft. above O.D. The operations, which were carried out by Messrs. Vivian's Boring and Exploration Company, Limited, under the management of Mr. Fisher Ray, were begun in August 1918, and were completed in July 1920, after a depth of 2,203 ft. had been reached. The object of the boring was to ascertain the character of the Lower Coal Series present in the eastern limb of the synclinal fold that forms the northern point of the Bristol coalfield. An almost continuous series of cores was obtained by drilling from the surface down to the bottom of the borehole; and through the kindness of Mr. R. M. Dillwyn of Bridgend, Glamorgan, permission was granted to the Geological Survey to examine the rocks thus displayed. A series of rock-samples and fossils was collected, and these are now included in the Survey Collections at Jermyn Street.

The following is an abstract section of the borehole :—

	Thickness. Ft.	in.	Depth. Ft.	in.
Soil and rubble	2	9	2	9
Coal Measures—				
Pennant Series :—				
Grey pennant sandstone with beds of grey sandy shale and a seam of fireclay. Sandstones contain many films of coal, ironstone-nodules, and a few pebbles of coal	853	5	856	2
Soft coal		2	856	4
Strong grey fireclay and grey sandy shale with ironstone	31	5	887	9
Coarse grey conglomerate with many large sub-angular pebbles of quartzite, &c.	4	9	892	6
Bluish-grey and red marls	41	3	933	9
Coarse grey conglomerate, as above	10	9	944	6
Bluish-grey and red marls	6	0	950	6
Grey shaly sandstone	5	3	955	9
Grey conglomerate with many large pebbles	28	7	984	4
Grey pennant sandstone with bands of shale and conglomerate. Joint planes lined with calcite	74	6	1,058	10
Lower Coal Series :—				
Bluish-grey and red marls	8	8	1,067	6
Grey quartzose sandstone	1	9	1,069	3
Bluish-grey sandy shale	19	9	1,089	0
Fine grey sandstone with courses of conglomerate	1	6	1,090	6
Grey and red sandy shale	5	3	1,095	9
Grey shale	35	0	1,130	9

[1] New Series 1-in. Ordnance Map, Sheet 251 (Malmesbury); 6-in. map Gloucestershire 69 S.W.; Old Series 1-in. Geological Map 35, Lat. 51° 32′ 24″, Long. 2° 26′ 12″.

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Coal—*continued.*	Thickness.		Depth.	
Lower Coal Series—continued.	Ft.	in.	Ft.	in.
Grey sandstone with bands of shale and conglomerate	6	3	1,137	0
Coal		9	1,137	9
Fireclay, sandy shale, and sandstone	20	7	1,158	4
Grey shale	17	0	1,175	4
Coal		2	1,175	6
Fireclay	11	9	1,187	3
Grey shale with a band of grey sandstone, 6 ft. thick, between 1,205 ft. and 1,211 ft. *Marine Band* at 1,227 ft.	68	3	1,255	6
Black shale	3	0	1,258	6
Coal	1	9	1,260	3
Grey fireclay and shale	12	0	1,272	3
Dark-grey and red mottled marl	5	0	1,277	3
Grey shale	18	3	1,295	6
Coal		3	1,295	9
Red and grey mottled marl	53	0	1,348	9
Grey shale	36	3	1,385	0
Coal, soft		3	1,385	3
Grey shale	107	0	1,492	3
Grey sandstone	16	5	1,508	8
Grey shale, numerous plant remains throughout	19	1	1,527	9
Coal, soft	1	6	1,529	3
Coal, soft, and black shale, mixed	1	10	1,531	1
Coal, soft	2	6	1,533	7
Dark shale		10	1,534	5
Dark shale and coal with numerous poorly preserved plants	1	0	1,535	5
Dark grey shale	29	1	1,564	6
Coal	1	0	1,565	6
Grey shale and shaly sandstone. *Marine Band* at 1,610–1,616 ft.	67	3	1,632	9
Red and bluish grey marl	19	3	1,652	0
Dark-grey shale	3	0	1,655	0
Coal		4	1,655	4
Grey shale	37	3	1,692	7
Grey sandstone	6	0	1,698	7
Grey shale	82	9	1,781	4
Grey fireclay	2	0	1,783	4
Grey sandy shale	8	3	1,791	7
Grey sandstone	1	9	1,793	4
Grey sandy shale with numerous plant remains	19	10	1,813	2
Coal	2	0	1,815	2
Dark-grey shale and fireclay	10	6	1,825	8
Grey sandstone	1	10	1,827	6
Grey shale with band of ironstone	27	7	1,855	1
Grey fireclay	1	8	1,856	9
Coal, soft		8	1,857	5
Grey shale with band of ironstone	39	2	1,896	7
Coal, soft	1	2	1,897	9
Dark shale and fireclay	33	7	1,931	4
Grey sandstone		10	1,932	2
Dark-grey shale	.3	9	1,935	11
Coal, soft		9	1,936	8
Dark shale	1	6	1,938	2
Coal, soft		8	1,938	10
Dark shale	2	0	1,940	10
Coal, soft		9	1,941	7
Dark shale		9	1,942	4

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COAL—*continued.* *Lower Coal Series*—continued.	Thickness. Ft.	in.	Depth. Ft.	in.
Coal	3	2	1,945	6
Grey shale and sandstone	19	4	1,964	10
Coal	1	4	1,966	2
Grey shale, fireclay, and sandstone	49	5	2,015	7
Coal	4	0	2,019	7
Black shale		5	2,020	0
Coal	1	0	2,021	0
Dark shale	2	4	2,023	4
Fireclay	4	0	2,027	4
Grey shale	13	3	2,040	7
Coal		3	2,040	10
Fireclay, shale, and sandstone	32	0	2,072	10
Grey shale with band of ironstone	38	1	2,110	11
Coal, soft	1	2	2,112	1
Dark-grey shale with band of ironstone	91	3	2,203	4

The dip of the beds, taken at various intervals, appeared to range between 10° and 35°. The rock-sequence displayed in the cores is generally similar to that passed through at Winterbourne,[1] in the western part of the coalfield; but some minor differences were noted. The base of the Pennant Series has been drawn at the depth of 1,058 ft. 10 in., and its position in relation to the highest marine band is nearly the same as in the two corresponding levels at Winterbourne. Beds of coarse conglomerate form a characteristic feature in the lower part of the Pennant Series, although similar but thinner and less coarse pebbly bands occur also in the upper portion of the Lower Coal Series. Many of the pebbles are of large size, one, a grey quartzite from 980 ft., measuring 5 in. in length; and in appearance the conglomerates are identical with those passed through at Winterbourne. Dr. H. H. Thomas, who has examined the specimens, reports that the pebbles are for the most part fine-textured rocks, variously coloured green, grey, and pink, embedded in a matrix which is highly felspathic and quartzose, much of the quartz being opalescent. The chief rock-types are quartzites, rhyolites, and vein-quartz, and, excepting a specimen of a fine-grained brownish sandstone, possibly of Carboniferous age, the whole assemblage, which is seemingly identical with that found at Winterbourne, again suggests derivation from rocks of Pre-Cambrian formations. No pebbles of the older Palæozoic sediments were recognised. The majority of the pebbles are sub-angular, and their marked increase in size, as compared with the constituents of the Winterbourne conglomerates, suggests that the source of the material lay somewhere east or north-east of the coalfield, and may indicate the presence of a buried ridge of Pre-Cambrian rocks in that direction.

In the Lower Coal Series beds of sandstone resembling Pennant rock are present, but they are subordinate to the argillaceous sediments, which are chiefly of the mudstone type.

[1] T. C. Cantrill and B. Smith, 'On a Boring for Coal at Winterbourne, Gloucestershire,' 'Summary of Progress for 1918' (*Mem. Geol. Surv.*) 1919, pp. 53-57.

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The lower shales are remarkably slicken-sided. Most of the coals are soft and thin, and are frequently interbedded with shale. A seam of good quality, 4 ft. thick, was passed through between the depths of 2,015 ft. 7 in. and 2,019 ft. 7 in. It is separated from a lower coal, 1 ft. thick, by 5 in. of black shale. Two marine bands were detected in the measures. At 1,227 ft. fragments of *Lingula* were found in association with numerous shells of *Orbiculoidea nitida* (Phill.); and between the depths of 1,610 and 1,616 ft. the shales yielded several finely ribbed specimens of *Productus*. These marine bands appear to represent similar horizons passed through at the depths of 1,090 and 1,488–1,494 ft. in the Winterbourne boring. Some of the shales were found to be crowded with plant-remains, but considerable thicknesses yielded no fossils. The identification of the plants by Dr. R. Kidston F.R.S. is as follows :—

	Depth in Feet.
Alloiopteris (Corynepteris ?) coralloides (*Gutbier*)	1,909
Linopteris *cf.* obliqua *Bunbury*	1,171
Lonchopteris bricei *Brongn.*	1,974
Mariopteris sp.	1,171
Neuropteris tenuifolia (*Schloth.*)	1,525, 1,711
,, sp.	1,525, 1,697,1,711, 1,719
Pecopteris (Dactylotheca ?) sp.	1,697
,, sp.	1,562
Sphenopteris *cf.* artemisiæfolioides *Crepin*	1,525
,, obtusiloba *Brongn.*	1,711
,, sp.	1804–1810
Calamites cisti *Brongn.*	,,
,, sp.	,,
Annularia microphylla *Sauveur*	1909
Asterophyllites equisetiformis *Schloth.*	1,525
Palæostachya sp.	1,973
Lepidophyllum lanceolatum *L. & H.*	1,711
Sigillaria mammillaris *Brongn.*	1,510
Cordaites principalis (*Germar*)	1,525
,, sp.	1,711, 1,804, 1810

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APPENDIX V.

TOTAL QUANTITY OF TIN, COPPER, AND OTHER MINERALS PRODUCED IN DEVONSHIRE, PARTICULARLY WITH REGARD TO THE AMOUNTS RAISED FROM EACH PARISH.[1]

By Donald A. MacAlister, A.R.S.M.

Many of the mines of Devon, like a still greater number in Cornwall, have long since been abandoned, and the topographical positions of such as are mentioned in records have only been determined after laborious examination of hundreds of old mine-plans preserved in local estate offices and institutions; in the Office of Woods and Forests, the Home Office, the Duchy Office and the Geological Survey, as well as a number in private ownership. It was only by this means that the recorded output of minerals could be classified according to parishes.

The tabulation of the production according to parishes presents a shorter and more rational account of the economic value of a mineral tract of country than could be obtained by a detailed list of outputs from the individual mines.

The totals from each parish during the periods are computed from the separate returns of the mines in them, as derived from the various sources mentioned on p. 274 of the *Geology of Falmouth and Truro*. As it was not until 1882 that continuous and reliable returns were published, it is likely that the details of the Tables fall short of the true amounts raised in the periods covered, and the reservations stated in the *Summary of Progress* referred to, as well as those in the memoir last cited (p. 274) must be borne in mind when considering the value of any mineral area. It will be recognised that although the records of early production are fragmentary there is enough evidence of different kinds to show that several of the ores have been worked from time to time for centuries past, and that it is impossible to embody such information in the Tables.

Mr. Lewis[2] states that the statistics of the production of tin from Cornwall and Devon in the late 12th century are not plentiful and relate mostly to Devonshire. From his perusal of the pipe-rolls Mr. Lewis was able to draw up tables of annual returns in which, however, there are many lacunæ amounting in the aggregate to several hundred years. The value of any attempt to estimate the quantities produced in the missing

[1] For the output from the parishes of Cornwall *see* 'Summary of Progress of the Geological Survey of Great Britain for 1906' (*Mem. Geol. Surv.*), Appendix II, 1907, p. 132.

[2] '*The Stannaries*', 1908.

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years would, at best, be doubtful, as even if the existing records were reliable, we should still have to assess the effect on production due to wars and social conditions, in addition to the usual uncertain elements in mining and trade. It may be noted, however, that from the 13th century to the middle of the 18th century many tens of thousands of tons of metallic tin were produced from the West Country.

With regard to copper it is quite certain that the ore was raised concurrently with tin-ore from the earliest historical times; but Lysons states[1] that in 1811 only seven mines in Devon were yielding copper, and that in that year the production was as follows:—Wheal Friendship, 110 tons; Wheal Crebor, 1,308 tons; Crowndale, 863 tons; East Crowndale, 913 tons; Wheal Hockworthy, 10 tons.

The early official statistics are far from satisfactory, and although care has been taken in the Tables which follow to present a true account in accordance with available data, the amounts here given should be regarded merely as useful guides to the relative importance of the mineral areas.

We may briefly recall the fact that the available records contain many lacunæ and probably mistakes,[2] so that although we know the sources we do not know the precise extent of the errors likely to be present. The observations contained in Appendix II. of the *Summary of Progress* already referred to apply with equal force to the mineral output of Devon and need not be repeated.

The periods covered by the Tables are necessarily restricted to the 19th and 20th century, as earlier records are scarce and discontinuous.

The principal production of lead ore was in the forties and fifties of the 19th century, though it continued to be raised until the eighties; the silver was obtained mainly from the lead. We recall, however, the historical fact that the silver-lead mines of Devonshire were worked at least as far back as the 13th century.[3] Manganese was actively mined in the seventies, but we note that considerable quantities of this ore, as well as iron ore, were raised in the 18th as well as the early part of the 19th century.[4] Zinc ore was raised mainly in the fifties and sixties. The output of tin ore, as expressed in the Tables, is limited to that since 1852; of copper ore since 1821; of lead ore since 1845; of silver since 1852, and of miscellaneous minerals since 1853.

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[1] *Mag. Britt.*, Devon, p. cclxxxiii.

[2] Such as those due to confusion between the natural and dressed ores and the metal, as well as to false returns.

[3] *See* 'Geology of Cornwall, Devon and West Somerset' (*Mem. Geol. Surv.*), pp. 611, 612.

[4] *Op. cit.*, pp. 610, 617.

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TABLE I.—*Output of Tin and Copper from the Mines of Devonshire, grouped according to the Parishes in which they occur. The Tin Ore produced from* 1852 *to* 1913; *and the Copper Ore from* 1821 *to* 1913.

Parish.	Black Tin.	Copper Ore.	Copper.[1]	Parish.	Black Tin.	Copper Ore.	Copper.
	Tons	Tons.	Tons.		Tons	Tons.	Tons.
Ashburton -	804	421	17	Molland - -	—	1,180	75
Beer Ferris -	10	205	13	North Bovey -	1,314	—	—
Belstone -	1	4,036[2]	375	North Molton	—	4,515	638
Bovey Tracey	—	2,300	86	Okehampton -	—	2,656	186
Buckfastleigh -	—	29,680	1,965	Peter Tavy, *see* Mary Tavy.	—	—	—
Buckland Monachorum	12	24,250	1,400	Plympton St. Mary - -	1,300	240	12
Chagford - -	60	—	—	South Tawton	—	6,285	344
Dartington -	56	—	—	Sydenham Damerel -	—	80	5
Holne - -	6	—	—	Tavistock -	300	933,210	59,682[3]
Ilsington -	91	—	—	Walkhampton	220	280	21
Lamerton -	61	22,600	1,285	Whitchurch -	515	20,630	1,538
Lydford - -	295	—	—	Miscellaneous -	10	1,150	80
Manaton -	203	—	—				
Mary Tavy -	408	43,250	4,015				
Meavy - -	400	—	—				

[1] Obtained from the copper ore mentioned in the previous column.
[2] Over 1,000 tons contained about 9 per cent. copper.
[3] In addition, about 90 tons of 'precipitated copper' yielding 70 per cent. of the metal.

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TABLE II.—*Output of Minerals, other than Tin and Copper, from the Mines of Devonshire, grouped according to the Parishes in which they occur. The Lead Ore raised since* 1845; *the Silver since* 1852; *and the Miscellaneous Minerals since* 1853; *to* 1913.

Parish.	Lead Ore.	Lead.[1]	Silver.[2]	Pyrites (Iron and Arsenical).	Arsenic[3] Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	
Ashburton - -	—	—	—	720	903	22,060	The pyrites mostly arsenical. The iron oxides are 'Brown Hæmatite,' ochre and umber. Of this, 12,820 tons of ochre and umber were returned from 'Roborough' and 'Devon and Cornwall' Mines, and some from 'S. Devon Mine,' which also returned 690 tons 'spathic iron.'
Beer Ferris - -	25,670	16,324	534,010	20	—	—	The pyrites non-arsenical. Also 3,240 tons of fluor-spar.
Belstone - - -	—	—	—	102	21	—	Of the pyrites, 72 tons were arsenical.
Bovey Tracey - -	—	—	—	—	—	2,878	Of which 1,060 tons 'micaceous' iron ore, 123 tons ochre and 667 tons 'Brown Hæmatite.'
Bratton Fleming -	—	—	—	—	—	20	Red Hæmatite. Also 10 tons of manganese ore, part of which came from Sherwell Parish, *q.v.*
Brentor - - -	—	—	—	—	—	155	Ochre. Also 3,610 tons of manganese ore.
Bridford - - -	—	—	—	—	—	—	21,250 (?) tons of barytes.
Brixham - - -	—	—	—	—	—	196,311	Mainly 'Brown Hæmatite,' containing up to 50 per cent. iron. Some micaceous and some sold as ochre and 'Wolston's iron paint.'

[1] From the lead ore. [2] From the lead. [3] In addition to the arsenical pyrites.

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TABLE II.—*continued.*

Parish.	Lead Ore.	Lead.	Silver.	Pyrites (Iron and Arsenical).	Arsenic Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	
Buckfastleigh	—	—	—	350	—	—	Of which a proportion was arsenical.
Buckland Monachorum	—	—	—	7,575	1,715	—	Pyrites mainly arsenical.
Budeaux	62	36	1,436	—	—	—	
Challacombe	—	—	—	—	—	50	'Brown Hæmatite.'
Chevelstone	—	—	—	—	—	300	'Brown Hæmatite.'
Christow	26,550	17,506	367,230	—	—	689	Of the iron oxides, 48 tons were ochre and umber; 240 tons 'Brown Hæmatite,' and 182 tons 'spathic iron ore' (*see* Lustleigh). In addition, 180 tons of fluor-spar and 1,635 tons of zinc-ore.
Combe Martin	860	545	812	—	—	1,340	Of the iron ore, 450 tons were 'Brown Hæmatite,' and 890 tons 'umber.' In addition, 1,590 tons of 'spathic iron ore.'
Coryton	—	—	—	—	—	—	*See* Milton Abbot.
Georgeham	—	—	—	—	—	780	'Brown Hæmatite.'
Harford	—	—	—	—	—	900	'Brown Hæmatite.'
Hennock	800	550	1,190	—	—	1,935	The oxide of iron was 'micaceous iron ore.' In addition, 1,200 tons of manganese ore.
Ilsington	93	60	80	—	—	46,512	Of the iron oxides, 21,928 were magnetite, 16,209 'Brown Hæmatite,' 5,717 mixed 'Brown Hæmatite' and micaceous iron ore ('shining ore'), containing up to 57·5 per cent. of iron, 708 tons of ochre, 340 tons of umber, 220 tons of so-called 'Wolston's iron paint.' In addition, 1,474 tons of zinc-ore.

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Kingsbridge	—	—	—	—	—	54	'Brown Hæmatite.'
Lamerton	62	39	2,915	1,410	1,011	—	Of the pyrites, 350 tons were arsenical. In addition, 602 tons of zinc ore and 77 tons of manganese ore.
Lew Trenchard	—	—	—	—	—	—	156 tons of Manganese ore. *See also* Marystow and Milton Abbot.
Lustleigh	—	—	—	—	—	1,580	Part of this from Bovey Tracey and Shuttamoor in Christow; 342 tons were 'Brown Hæmatite,' and the rest 'shining ore.'
Lydford	12	8	—	—	—	—	
Marlborough	—	—	—	—	—	100	
Marystow	—	—	—	—	—	—	1,820 tons of manganese ore, but this includes some from Milton Abbot, Lew Trenchard, Cardwell and St. Stephen.
Mary Tavy	2,000	1,176	9,150	17,875	7,685	—	Of the pyrites, 10,508 were arsenical. In addition, 160 tons of zinc ore. 'Scheelite,' and 1 ton of Wolfram from Wheal Friendship.
Milton Abbot	—	—	—	—	—	—	49,890 tons of manganese ore, but part of this came from Lifton, Sydenham Damerel, Lew Trenchard and Coryton. *See also* Marystow.
Molland	—	—	—	—	—	28,560	'Brown Hæmatite.'
North Bovey	—	—	—	—	—	25	Specular iron or 'shining ore.'
North Molton	25	9	—	150	—	17,081	Of the iron oxides, 14,181 tons were 'Red Oxide,' and 2,900 'Brown Hæmatite.' In addition, 9,625 tons of 'spathose iron' and 86 tons of manganese ore. The pyrites was non-arsenical.
Newton Abbot	—	—	—	—	—	—	40 tons of manganese ore.
Newton St. Cyres	—	—	—	—	—	—	1,401 tons of manganese ore.
Peter Tavy	—	—	—	—	—	—	*See* Mary Tavy.
Plympton St. Mary	771	367	12,050	911	270	—	Of the pyrites, 210 tons were arsenical. In addition, 8 tons of zinc ore.
Rattery	—	—	—	—	—	4,400	'Brown Hæmatite.'

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TABLE II.—*continued.*

Parish.	Lead Ore.	Lead.	Silver.	Pyrites (Iron and Arsenical).	Arsenic Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	
St. Stephen	—	—	—	—	—	—	Manganese, *see* Marystow.
Shaugh Prior	—	—	—	—	—	5,317	Mainly 'Brown Hæmatite,' 250 tons were 'Red Hæmatite.'
Sherwell	—	—	—	—	—	535	'Brown Hæmatite.' In addition, 55 tons manganese ore, *see* Bratton Fleming.
South Molton	80	60	64	—	—	—	
Stoke Gabriel	—	—	—	—	—	4,790	'Brown Hæmatite.'
Sydenham Damerel	100	69	947	—	—	—	140 tons Zinc ore. For Manganese, *see* Milton Abbot.
Tavistock	1,300	931	13,144	72,001	86,460	4,290	Of the pyrites, 50,393 tons were arsenical and 3,823 mixed 'crude arsenic and arsenical pyrites.' Oxides of iron as ochre and umber. In addition, 30 tons of wolfram and 60 tons of fluor-spar.
Ugborough	285	171	2,688	—	—	2,432	Of the iron oxide, 2,233 tons were 'Brown Hæmatite' and 199 tons ochre.
Walkhampton	—	—	—	—	2	—	
Whitchurch	12	7	—	152	—	—	Of the pyrites, 33 tons arsenical.
Wolborough	—	—	—	—	—	1,240	'Brown Hæmatite.'
Yealmpton	—	—	—	—	—	250	'Brown Hæmatite.'
Miscellaneous (unclassified)	740	565	2,575	—	—	—	160 tons of Manganese ore from 'Rostidyon' and 'Fullabrook.' 640 tons of iron ore from 'Furgam Mill' (? Brixham). The lead-ore is from 'Park,' 'South Maex,' 'True Blue,' 'Thomas United' and 'New Devon Consols.'

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„ 1913	1*s.* 0*d.*		

Recent Publications.

Memoirs.

	s.	*d.*
A Short Account of the Geology of the Isle of Wight. By H. J. Osborne White, F.G.S.	10	0
The Water Supply of Buckinghamshire and of Hertfordshire from Underground Sources. By W. Whitaker, B.A., F.R.S.	16	0
The Water Supply of Norfolk from Underground Sources. By W. Whitaker, B.A., F.R.S.	10	0

Maps.

One-inch scale, England and Wales—	
Sheet 269 (Windsor and Chertsey)	each, 2 0
Sheet 228 (Haverfordwest), Drift Edition	
Sheet 228 (Haverfordwest), Solid Edition	
One-inch scale, Scotland—	
Sheet 53 (Ben Nevis)	each, 3 0
Sheet 81 (Applecross)	
Four Miles to one-inch scale, Scotland—	
Sheet 6, Caithness (part of), Thurso and Wick	each, 3 0
Sheet 13, Argyllshire (part of), Knapdale, Jura, Islay and Colonsay	

Other Memoirs in course of Publication.

Geology of the South Wales Coalfield—Part XIII.—Country around Pembroke and Tenby

Geology of South London

Water Supply of Cambridgeshire, Huntingdonshire and Rutland

Economic Geology of the Central Coalfield of Scotland—Area IX.—including the Districts of Carluke, Strathaven and Larkhall

Description of Arthur's Seat Volcano (Second Edition)

Printed under the authority of His Majesty's Stationery Office
By Eyre and Spottiswoode, Ltd., East Harding Street, E.C. 4,
Printers to the King's most Excellent Majesty.

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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

MEMOIRS OF THE GEOLOGICAL SURVEY

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY OF GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1921

WITH

REPORT OF THE GEOLOGICAL SURVEY BOARD

AND

REPORT OF THE DIRECTOR

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S
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1922

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REPORT

OF THE

GEOLOGICAL SURVEY BOARD

FOR 1921

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

MAY IT PLEASE YOUR LORDSHIPS,

In accordance with our terms of reference, we, the Geological Survey Board, beg to submit our second Annual Report of the work of the Survey and Museum.

1. In our previous Report we referred to some of the economic aspects of the work of the Survey which could not be effectively dealt with unless the provision for systematic survey and revisions of survey were extended. We were then in a position also to report that on a complete statement of these matters, sanction had been given for a permanent increase of the establishment of the Survey amounting to half of that required for the full provision contemplated, and that this additional personnel had been secured.

Thus in the work of the past year it was possible to make a start on a programme drawn with a view to a material expansion of the area under survey. That programme, which was outlined in our last Report, has been followed, with the result that in the course of 1921 seven field units in all have been engaged on field work. A field unit, it may be noted, consists normally of a District Geologist with four Geologists; but the number of Geologists is varied where circumstances make some other arrangement desirable.

Four field units have been engaged on surveys previously in hand, viz. :—

(*a*) London and South Eastern District (primary six-inch survey).

(*b*) Midland District (primary six-inch survey).

(*c*) South-West Highland District (primary six-inch survey)—summer part of field season; and Ayrshire Coalfield Revision—remainder of season.

(*d*) North Highland District (primary six-inch survey)—summer part of field season; and Central Coalfield of Scotland Revision—remainder of season.

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Three field units have commenced re-surveys in areas for which revision has long been overdue, viz. :—

(*e*) Northumberland and Durham District.
(*f*) Cumberland District.
(*g*) Lancashire District.

The re-survey work in Lancashire could not be taken up until late in the year, when the completion of certain work in North Wales and Shropshire set free geologists required for the establishment of the new field unit.

2. The Director's Report for 1921, which is presented herewith, gives particulars of the field work which has been carried out in the year, with the related preparation and publication of maps and memoirs, the work of the Headquarters staff on petrological, palæontological and chemical questions. It also deals with the changes and developments in the collections and Library in the Museum of Practical Geology.

We are satisfied that in the past year the Survey has made good progress in the programme of field work, in the discussion and publication of the results of this work and in steadily accumulating and examining at Headquarters those examples and records obtained which bear on scientific and economic questions in British Geology.

3. As explained above, reference was made in our last Report to our recommendations for an addition to the staff; we then mentioned that authority had been given for an immediate addition to the personnel amounting to one-half of the full expansion contemplated. In the course of the year under report this authority was extended so as to provide for the full increase of staff originally proposed. Accordingly it has been possible to recruit four more geologists to the staff. There remain at present only four vacancies in this grade and it is anticipated that these vacancies will be filled this year.

4. Local headquarter offices have been opened as centres for the work of three areas, viz., in Newcastle for the Northumberland and Durham area; in Whitehaven for the Cumberland area and in Manchester for the Lancashire area. The requirements of the work in Scotland have outgrown the possibilities of the headquarters office there, but additional accommodation has been provided close by.

5. We have arranged for the Geological Survey to co-operate with the Fuel Research Board in their survey of coal seams from the fuel point of view. The work of this survey is to be carried out under local committees and the first of these has been established in the Lancashire area. The officers of the Geological Survey in that area will assist in bringing the available geological information into relation with the physical and chemical investigations carried on for the Fuel Research Board.

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6. At your Lordships' request we advised upon the revision of the salary scales of the scientific staff of the Geological Survey and Museum, and we reported that scales which have now been approved, while not in all respects such as would place the Survey permanently on a satisfactory basis, will suffice till 1924, when they are to be reconsidered.

7. The programme of field work for 1922 is—

(*a*) to prosecute the primary six-inch survey in continuation of the work of the past year in the London and South-Eastern District, in the Midlands, in the West Highlands, and in the North Highlands;

(*b*) to carry on revision of the six-inch surveys in Northumberland, in Cumberland, in Lancashire, in Ayrshire, and in the Central Coalfield of Scotland; also, if recruitment of staff permits, to make a beginning with the revision of the Fifeshire and Yorkshire Coalfields;

(*c*) to continue on the lines laid down last year (*a*) survey work bearing on metalliferous mining; and (*b*) the collection and examination of information obtainable from boreholes and other exploratory operations.

In view of the expansion which is taking place in the staff, the arrangements for work, not only in the field but also at headquarters, must at present be considerably influenced by consideration for the professional training of the new members of the staff.

F. G. OGILVIE,
Chairman.

May 1922.

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REPORT

OF THE

DIRECTOR

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1921

A district office was opened in November at 21, Albion Street, Gaythorne, Manchester, and placed in charge of Mr. W. B. Wright, District Geologist, who with three Geologists has carried on work during the past field-season in Sheet 76 (Rochdale), thus initiating the revision of the Lancashire coalfield.

There are also district offices in Whitehaven under Mr. Bernard Smith and in Newcastle-on-Tyne under Mr. R. G. Carruthers, from which the revision of the Cumberland and Westmorland and of the Northumberland and Durham districts was begun in 1921. Draughtsmen are attached to the Newcastle-on-Tyne and Whitehaven offices, but it has not yet been possible to provide one for the Manchester office.

The other districts in which mapping is in progress are the same as in 1920. In the West Midlands of England, the Shropshire, Warwickshire and Staffordshire areas have been consolidated into one field district under the charge of Mr. T. C. Cantrill.

Special attention has been directed to collecting information about bores in progress both in England and in Scotland, and many cores have been inspected and checked by geologists.

The bores in search of petroleum in the Chesterfield, Mansfield and Staffordshire districts have been geologically examined and visits have been paid to the Kimmeridge Shale area in Norfolk and to the Kelham oil-boring. A complete series of samples from the Petroleum Department's bores is now preserved in the Museum of Practical Geology or in the Survey Office in Edinburgh.

A complete revision of the known British sources of barytes, witherite, manganese and tungsten has been in hand during the year and new editions of the Special Mineral Resources Reports

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on these minerals are in manuscript or in the press. Information has also been collected regarding other mineral deposits as occasion arose. The copper ores of England and Wales have received special attention.

Advice and assistance in geological matters have been given to many public departments.

A large number of enquiries on geology especially in its application to industry have been received from the general public and commercial firms. The following are a few of the principal subjects: wells and bores for water; ironstone, peat, concrete, oil-shale, soapstone, sands, coal, soils, mineral oil, china-clay, sillimanite, gypsum, roadstones, setts, copper and lead ores, barytes, brick clays, precious stones.

(1)—ENGLAND AND WALES

Field Survey on the six-inch scale

London District.—Field survey was continued in Sheets 239 (Hertford), 256 (North London), 271 (Dartford), and commenced in Sheets 257 (Romford), 272 (Chatham), 287 (Sevenoaks) and 288 (Maidstone) by Dr. Sherlock, Mr. Bromehead and Mr. Dines, with Mr. Dewey as District Geologist.

Shropshire, Warwickshire and Staffordshire District.—Work was continued in Sheets 138 (Wem), 139 (Stafford), 151 (Welshpool), 152 (Shrewsbury), 153 (Wolverhampton), 167 (Dudley) and 168 (Birmingham) by Messrs. Wedd, Dixon, Sherlock, Pocock, Whitehead and Robertson, under the superintendence of Mr. Cantrill, District Geologist.

Lancashire District.—Work was commenced in Sheet 76 (Rochdale) by Mr. Wright, District Geologist, and Dr. Sherlock, Mr. Wray and Mr. Lloyd.

Cumberland District.—Sheets 17 (Carlisle) and 28 (Whitehaven) were commenced by Messrs. Dixon, Eastwood, Maden, and Trotter, under the superintendence of Mr. Bernard Smith.

Northumberland District.—Work was commenced in Sheets 1 (Norham), 2 (Berwick), 3 (Ford), and 4 (Holy Island) by Mr. R. G. Carruthers, District Geologist, with Messrs. Dinham, Burnett, Marsden and Fowler.

In preparation for the publication of a New Series colour-printed edition of Sheet 313 (Shaftesbury), Mr. Dines and Mr. Hollingworth under the superintendence of Mr. Howe, have revised the boundaries of certain formations within that sheet.

Indoor Work

The manuscripts of the following memoirs are being written or edited for publication:—

Special Reports on the Mineral Resources of Great Britain:—

Tungsten and Manganese Ores, 3rd Edition (Vol. I).
Lead and Zinc Ores of the Pennines, Part I. Northumberland and Alston Moor.
Lead and Zinc Ores of the Pennines, Part II. Yorkshire, etc.
Copper Ores of the West of England.
Copper Ores of the Midlands, the Lake District, and North Wales.
Refractory Materials: Fireclays. Chemistry and Physical Tests.
Water Supply of Wiltshire.
Water Supply of Gloucestershire.
Palæontological Monograph on Carboniferous Plants. Parts I and II.

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Geology of London District (2nd Edition).

Soils and Subsoils with especial reference to London and its neighbourhood (3rd Edition).

The Concealed Mesozoic Rocks in Kent.

Explanations of Sheets 96 (Liverpool); 108 (Flint); 168 (Birmingham); 169 (Coventry); 238 (Aylesbury); 255 (Beaconsfield); and 313 (Shaftesbury).

The following maps and memoirs were published or passing through the press in 1921 :—

I.—MAPS

Published.

½-inch to 1 mile :—

Sheet 19 (Bath, Guildford, Abingdon, Southampton). New Edition.

1 inch to 1 mile :—

Sheet 244 (Linney Head, drift edition), Sheet 245 (Pembroke, drift edition), Sheet 270 (South London, drift edition).

6 inches to 1 mile :—

Derbyshire, 11 N.W., S.W., S.E.; 12 N.W., N.E., S.W., S.E.; 13 N.W., S.W.; 17 N.W., N.E., S.W., S.E.; 18 N.W., N.E., S.W., S.E.; 19 N.W., S.W.; 25 N.W., N.E., S.W., S.E.; 26 S.W.; 30 N.W., N.E.,S.W., S.E.,; 31 N.W., S.W.; 35 N.E., S.W., S.E.; 36 N.W., S.W.

Pembrokeshire, 21 N.E., S.E.; 26 N.E., S.W. and S.E.; 27 S.W., S.E.; 32 N.E.; 33 N.W., N.E.; 34 N.W., N.E., S.E.; 35 N.W., N.E., S.W., S.E.; 36 N.W., S.W.; 41 N.W., N.E.

In the press, engraving or colour-printing.

1 inch to 1 mile :—

Sheet 154 (Lichfield), Sheet 169 (Coventry), Sheet 226/7 (Milford), Sheet 255 (Beaconsfield), Sheet 231 (Merthyr Tydfil) (New edition, solid and drift), Sheet 249 (Newport) (New edition, solid and drift), Sheet 96 (Liverpool), Sheet 238 (Aylesbury).

6 inches to 1 mile :—

Derbyshire, 26 N.W.; 35 N.W.

Staffordshire, 45 S.W., S.E.; 51 N.W., N.E., S.W., S.E.; 57 N.W., N.E., S.W., S.E.; 63 N.W., N.E., S.W., S.E.

Warwickshire, 9 N.E., S.E.; 10 N.W., N.E., S.W., S.E.; 11 S.W.; 15 N.E., S.E.; 16 N.W., N.E., S.W., S.E.; 17 N.W., S.W.; 20 N.E., S.E.; 21 N.W., N.E., S.W., S.E.; 22 N.W., S.W.

Copies of the following six-inch sheets, which are not to be published, were deposited in the Library for public reference :—

Cheshire, 6 S.E.; 7 N.W., N.E., S.W., S.E.; 12 N.W., N.E., S.W., S.E.; 13 N.W., N.E., S.W., S.E.; 14 S.W.; 21 N.E.; 22 N.W.

Hertfordshire, 20 S.W., S.E.; 28 N.W., N.E., S.W., S.E.; 35 N.W., N.E., S.W., S.E.; 39 N.E., S.E.; 40 N.W., S.W.

Kent, 2 S.W., S.E.; 8 N.W., N.E., S.W., S.E.; 9 S.W.

II.—MEMOIRS

Published.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1920. 111 pp.; 3 text-figures. 1921. Price 3*s.* 6*d.* net.

Special Reports on the Mineral Resources of Great Britain :—

Vol. XVIII.—Rock-Salt and Brine. By R. L. Sherlock, D.Sc., 123 pp.; 2 plates; 16 text-figures. 1921. Price 5*s.* net.

Vol. XIX.—Lead and Zinc Ores in the Carboniferous Rocks of North Wales. By B. Smith, M.A. 162 pp.; 3 plates; 25 text-figures. 1921. Price 5*s.* 6*d.* net.

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Vol. XXI.—Lead, Silver-Lead and Zinc Ores of Cornwall, Devon and Somerset. By H. Dewey. 72 pp.; 18 text-figures. 1921. Price 2*s.* 6*d.* net.

Vol. XXII.—The Lead and Zinc Ores of the Lake District. By T. Eastwood, A.R.C.S. 56 pp.; 1 plate; 4 text-figures. 1921. Price 2*s.* net.

A Short Account of the Geology of the Isle of Wight. By H. J. Osborne White, F.G.S. 219 pp.; 1 plate; 43 text-figures. 1921. Price 10*s.* net.

The Water Supply of Norfolk from Underground Sources. By W. Whitaker, B.A., F.R.S. 185 pp. 1921. Price 10*s.* net.

The Water Supply of Buckinghamshire and Hertfordshire from Underground Sources. By W. Whitaker, B.A., F.R.S. 368 pp. 1921. Price 16*s.* net.

The Geology of the South Wales Coalfield. Part XIII. The Country around Pembroke and Tenby. (Explanation of New Series Sheets 244 and 245.) By E. E. L. Dixon, B.Sc., F.G.S. 220 pp.; 5 plates; 13 text-figures. 1921. Price 8*s.* net.

The Geology of South London. (Explanation of New Series Sheet 270.) By Henry Dewey and C. E. N. Bromehead, B.A. 92 pp.; 3 plates; 1 text-figure. 1921. Price 3*s.* net.

In the press.

Special Reports on the Mineral Resources of Great Britain:—

Vol. II.—Barytes and Witherite. *Third Edition.*

Vol. XX.—Lead and Zinc. The Mining District of North Cardiganshire and West Montgomeryshire.

Vol. XXIII.—Lead and Zinc Ores in the Pre-Carboniferous Rocks of West Shropshire and North Wales.

The Water Supply of Cambridgeshire, Huntingdonshire and Rutland from Underground Sources.

---

(2)—SCOTLAND

Field-work

In Scotland each field unit as in previous years has spent part of the season in revising the maps of the coalfields and part in the primary survey of the Highlands.

Coalfield Revision.

Ayrshire.—Mr. E. B. Bailey, District Geologist, with Messrs. Anderson, Richey, Eyles and Simpson have continued survey work in Sheets 30 (Renfrew), 22 (Kilmarnock) and 14 (Ayr).

Lanarkshire, Clackmannanshire and Stirlingshire.—Mr. M. Macgregor, District Geologist, with Messrs. Wilson, Read, Haldane and Ross have continued the revision of Sheets 23 (Lanark) and 39 (Stirling).

Primary Survey.

West Highlands.—Work was commenced in Sheets 52 (Ardnamurchan) and 51 (Coll), by Messrs. Richey, Eyles and Simpson, under the superintendence of Mr. E. B. Bailey. Dr. G. W. Lee has examined the fossiliferous Secondary rocks.

North Highlands.—Mr. M. Macgregor, District Geologist, has been assisted by Messrs. Wilson, Read, Haldane and Ross in the survey of Sheet 102 (Lairg, Sutherlandshire).

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Indoor Work

The manuscripts of the following memoirs are being written or prepared for publication :—

Explanations of Sheets 84 (Nairn), 86 and 96 (Portsoy, Huntly, Banff), 44 (Oban and Mull), 54 (Moor of Rannoch).
The Cannel Coal, Lignite and Mineral Oil Resources of Scotland.
The Ayrshire Bauxitic Clay.
Economic Geology of the Central Coalfield of Scotland :—
Area VI. (Bathgate).

The following maps and memoirs have been published or are passing through the press :—

I.—MAPS

Published.

¼ inch to 1 mile :—

Sheet 6 (Caithness), Sheet 13 (Islay).

1 inch to 1 mile :—
Sheet 53 (Glencoe), Sheet 81 (Raasay and Applecross).

6 inches to 1 mile :—
Dumfries, 7 N.W.
Edinburgh, 10 N.E., S.W., S.E.
Lanark, 3 S.W.; 5 S.E.; 8 S.E.; 9 N.W., N.E., S.E.; 11 S.E.; 12 N.W., N.E., S.W., S.E.; 13 N.W., N.E.; 17 N.W., S.E.; 19 S.W.; 20 N.W., N.E., S.W., S.E.; 23 N.E., S.E.; 24 N.W., N.E.; 25 N.E.; 31 N.E.; 49 N.E., S.E.

Linlithgow, 3 S.W. (2nd Edition); 5 N.W., N.E., S.W., S.E.; 7 N.W. and S.W. (2nd Edition); 8 N.E., S.E.; 9 N.W., N.E. (2nd Edition), S.W., S.E. (2nd Edition); 10 N.W. (2nd Edition), S.W. (2nd Edition); 11 N.E., S.E.; 12 N.W., S.W.
Renfrew, 8 N.W., N.E., S.W., S.E.; 12 N.W.
Stirling, 24 S.E.; 28 N.E.; 30 N.W., N.E., S.W., S.E.; 31 N.W., S.W.; 32 N.W.; 34 (Dumbarton det.) N.W.; 35 N.W., N.E., S.W., S.E.; 36 N.W.

In the press, engraving or colour-printing.

1 inch to 1 mile :—

Sheet 37 (Mid Argyll), Special Map of Assynt District, Sheet 86 (Huntly), Sheet 96 (Banff), Sheet 54 (Rannoch Moor), Sheet 31 (Falkirk) (New Edition), Sheet 16 (Moffat) (New Edition), Sheet 44 (Mull).

6 inches to 1 mile :—

Lanark, 8 S.W.; 9 S.W.; 11 N.E.; 13 S.W., S.E.; 14 S.W.; 16 N.E.; 17 N.E., S.W.; 18 N.E., S.W.; 24 S.W., S.E.; 25 N.W.
Renfrew, 7 N.E., S.E.; 11 N.E., S.E.; 12 S.W.; 16 N.W., N.E.; 17 N.W.
Ayr, 8 N.E., S.E.; 11 N.E., S.W., S.E.; 12 N.W.; 16 N.W. and S.W., N.E., S.E.; 17 S.W.
Stirling, 25 S.W.; 28 S.E.; 29 N.W., N.E., S.W.

Copies of the following six-inch sheets, which are not to be published were deposited in the Office for public reference :—

Argyll, 52; 66 S.E.; 67; 69; 80 N.E., S.W.; 81; 82; 83; 93 N.W., N.E.; 122.
Ayr, 7 N.W., S.W. (New Series).

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II.—MEMOIRS

Published.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1920. *See* p. 7.

Description of Arthur's Seat Volcano. By B. N. Peach, LL.D., F.R.S. Second Edition. 26 pp.; 1 plate; 4 text-figures. 1921. Price 2*s.* 6*d.* net.

The Economic Geology of the Central Coalfield of Scotland :—
Area IX.—Carluke, Strathaven and Larkhall. By L. W. Hinxman, B.A., F.R.S.E., R. G. Carruthers, F.G.S.; M. Macgregor, M.A., B.Sc. and C. H. Dinham, B.A. 148 pp.; 6 plates; 2 text-figures. 1921. Price 8*s.* net.

Special Reports on the Mineral Resources of Great Britain :—
Vol. XVII.—The Lead, Zinc, Copper and Nickel Ores of Scotland. By G. V. Wilson, with contributions by John S. Flett, LL.D., F.R.S. 159 pp.; 2 plates; 16 text-figures. 1921. Price 7*s.* 6*d.* net.

PETROGRAPHICAL DEPARTMENT

Dr. Thomas has been engaged on the petrography of Sheets 44 (Mull), 14 and 22 (Ayrshire and Renfrewshire), 42 (Tiree), 43 (Iona) and 51 (Ardnamurchan).

600 rock sections were cut, of which 460 were Scottish, 128 English and 12 foreign and miscellaneous; 121 rock specimens were collected in Scotland from districts in which the geologists are surveying.

Descriptions of 354 rocks have been issued to the geologists engaged on field work.

The Petrographer has answered many enquiries received from Government departments and from the public.

PALÆONTOLOGICAL DEPARTMENT

From Shropshire, Cumberland and Somerset, principally, 4,594 fossils were collected during the year. The officers of the department have given much assistance in examining the cores of deep borings and determining horizons by the fossils obtained. Mr. Pringle has made a number of visits to various districts in North Wales, Dorsetshire, Wiltshire, Bedfordshire, etc., where special palæontological knowledge was required. Mr. Chatwin has been employed mainly in revising the Museum collections. Dr. Kitchin has been engaged on an investigation of the fossils of the Secondary rocks of Kent.

In Scotland 3,355 fossils were collected from borings and from natural exposures; many were obtained from the Brora area in Sutherlandshire by Dr. Lee and the fossil collectors.

CHEMICAL DEPARTMENT

Analyses have been made of 24 igneous and metamorphic rocks from Aberdeen, Banff and Mull, and of 14 fireclays. Partial analyses were also made of 2 Scottish iron ores, and the chemistry of the Strathmore meteorite was specially investigated by Mr. Ennos.

PHOTOGRAPHIC WORK

A large series of photographs was taken in the Isle of Wight, the London district and the Midlands. The new landscapes added to the collection number 356. More than 100 photomicrographs, enlargements, lantern-slides and diagrams were made for special purposes. The prints necessary for the photographic albums of English views have been prepared.

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In Scotland 89 views of geological interest were photographed in Mull, Iona and Staffa and the Lothians. The album of photographic prints is complete to the end of 1920.

The sale of prints and lantern-slides to the public during the year was: English, 336 prints and slides; Scottish, 338 slides, 38 prints and 2 enlargements.

MUSEUM OF PRACTICAL GEOLOGY

During the year 1921 the total number of visitors to the Museum has been 26,829; of these 21,845 visited the Museum on week-days in the day-time and 2,637 in the evenings; the number of Sunday visitors was 2,347.

Fifty-five demonstrations to schools and institutions have been given in the Museum during the year, the aggregate attendance being 1,090.

The London Model has been recoloured in accordance with the new six-inch geological maps, and a case of specimens, arranged to illustrate the stratigraphy and economic geology of the London district, has been placed on exhibition beside it. Progress has been made in the expansion of the economic collections and cases have been arranged to illustrate the uses of refractory materials, abrasives, sands and cements.

The collection of roadstones has been transferred to another case and rearranged and the space so liberated is being devoted to an exhibit of recent Survey maps and publications.

In the Mineral Department a series of six cases has been prepared to illustrate the Special Reports on Iron Ores, Volumes VIII to XII, dealing with the Hæmatite Ores of Cumberland and the Forest of Dean, Sundry Unbedded Ores and the Bedded Ores of the Lias and Oolite.

The cleaning and registration of specimens in the older part of the collection has been continued. Wall-cases 10 to 16, and 53 to 56, and Pedestal Cases 31 and 32 having been dealt with.

Twelve divisions of the Horseshoe Case have been cleaned and relined.

Collection and investigation of the British iron ores have been proceeded with, and the Frodingham and Cleveland Districts have been visited for this purpose.

The Library and Map Room have been used by the public and officials of other Departments in increasing numbers. The additions during the year comprise 182 volumes of independent works, 2,215 volumes and parts of serial publications, 536 maps, not including those bound in the foregoing, and 192 pamphlets. Author and Subject cards were typed for the above, and added to the Card Catalogue, and a number of worn cards were replaced.

The presentations during the year include a collection of papers, issued by the Geophysical Laboratory of the Carnegie Institution, Washington, and publications from the recently established Geological Surveys of Greece, Poland, Czecho-Slovakia, China, Sierra Leone, Nigeria and Uganda.

JOHN S. FLETT,
Director.

3rd March, 1922.

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List of Donations during the Year 1921

Ashcroft, F. N., Esq.—Three specimens of calcite, one specimen of pearl spar, two specimens of blende, New Glencrieff Mine, Wanlockhead. Specimen of lignite partially silicified, from Ireland. One cut ruby spinel, and one crystal of pennine from Zermatt, Switzerland.

Bailey, E. B., Esq., M.C., B.A.—Twelve micro-sections of rocks from Yorkshire.

Banfield, —., Esq.—Specimen of marcasite from River Adur, Shoreham.

Berry, James, Esq.—*See* Pistor.

Carley, George C., Esq.—Specimens of native sulphur with selenite from Girgenti, Sicily. A finely crystallised specimen of pyrite, from Ravi, Tuscany.

Carr, R. H., Esq.—A series of bauxite samples from the Three Friends Mine, Akyma, Demerara River, British Guiana; and one sample from the Surinaamsche Bauxite Maatischappij, Dutch Guiana.

Chatterton, F., Esq., F.R.I.B.A.—A specimen of *Stigmaria* from the Carboniferous rocks, bank of River Coquet, near Harbottle, Northumberland.

Clark, F. B., Esq.—A well preserved specimen of *Productus* of the group of *P. semireticulatus* (Martin), from the Coal Measures (near the Four Foot Coal), Aldridge Colliery, near Walsall.

Cole, R. Langton, Esq., F.R.I.B.A.—Series of negatives of photographs of geological interest made by the late J. J. Cole, Esq.

Cripps, A., Esq.—Serpentine powder from a well in Latakia, Syria.

Davis, A. G., Esq.—A specimen of *Melanopsis ancillaroides* (Desh.) from the Blackheath Beds of Charlton, Kent, figured by Dr. L. Dudley Stamp, *Proc. Geol. Assoc.*, vol. XXXII, part 2, 1921, pl. ii., fig. 8.

Duckworth, H., Esq.—Sett of Haslingden Flag, "Rosendale Granite."

Eastwood, Frank B., Esq.—Two specimens of native gold from the St. David's Mine and the Gwyn Mine, Merionethshire, respectively.

Gotham Company, Ltd., Messrs. The.—One alabaster bowl, one alabaster ash-tray and one alabaster slab, from Chellaston, Derby.

Gordon, H. S., Esq.—Monazite concentrates.

Gregory, Prof. J. W., F.R.S.—A specimen of *Rhaxella*-chert from the High Level Gravels (280 ft. above O.D.) in the upper Roding valley above Loughton, Essex.

Griete, Captain.—A series of mineral specimens from Brazil.

Hort, Gilbert, Esq.—Specimen of columbite from Namaqualand.

Hubbard, Theodore, Esq.—Specimen of native silver in a small vein of galena, blende and pyrite, with quartz.

Hutchinson, T. Anthony, Esq.—A series of samples of fire-resisting and filter bricks made largely of diatomaceous earth.

Johnstone, J., Esq., B.A., M.B., F R.C.S.—A specimen of gneiss showing glacial striæ and the effects of sea erosion.

Leese, J., Esq., M.A., Mus.B.—A small set of fossils from the Shineton Shales and a specimen of *Collyrites* from the Coral Rag of Upware, Cambridgeshire.

Lindsay, L., Esq.—Native tellurium from Colorado.

Mallett, Francis, Esq.—Two fine specimens of cut sapphire.

Matley, Dr. C. A.—Fifty-two micro-sections of rocks from the Lleyn peninsula, Carnarvonshire.

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MORLEY, E. H. E., ESQ.—Specimen of tin-ore from Katanga, Central Africa.

NOBLE AND COMPANY, MESSRS.—A specimen of facetted hæmatite.

O'DRISCOLL, FLORENCE, ESQ.—Cut tourmaline.

PALAGI, THE CONTE.—Specimens of anthracite from Sardinia, Italy.

PISTOR, M. LE GÉNÉRAL (per JAMES BERRY, ESQ.).—Specimen of selenite with sand ("rose-du-sable"), from the Sahara, at Bir Pistor, near Ghadames, South Tunisia.

POULAIN, A., ESQ. (per J. PRINGLE, ESQ.).—Six polished specimens of French marbles.

RAISIN, MISS C. A., D.Sc., F.L.S., F.G.S.—A series of 50 choice invertebrate fossils of various groups and ages.

REID, ALEXANDER, ESQ., M.INST.C.E., F.G.S.—A specimen of pitch from Wrentnall, Salop.

RILEY, COL. J. H. G.—Specimens of chromite, from Blomidon Mountain, York Harbour, Newfoundland.

RUTHERFURD, W. G., ESQ.—Specimen of verdite from South Africa.

SANDISON, W. G. W., ESQ.—Three specimens of uvarovite, from Hagdale, Unst, Shetland. Two samples of concentrates from Chromite Mine, Hagdale. A specimen of brucite, from Hagdale Bay, Shetland.

SAWYER, A. E. T., ESQ.—Five specimens of *Terebratula* and two of *Corynella* from the Inferior Oolite of Gloucestershire.

SCHAVERIEN, J., ESQ.—Rough beryl and tourmaline and a polished specimen of opal.

SHEPPARD, T., ESQ., M.Sc., F.G.S.—A token, issued by Henry Sneaton in 1667, bearing the device of three "snake-stones," the arms of Whitby.

SIMMONS, G. W., ESQ.—A set of 49 microscopic sections, chiefly of Carboniferous Limestone with corals from the Avon Gorge, Bristol.

SPATH, DR. L. F., F.G.S.—A series of 80 fossils (chiefly lamellibranchs, gasteropods and brachiopods) from the nodules of the Tardefurcata Bed near Leighton Buzzard.

STARTIN AND COMPANY, MESSRS.—A specimen of phlogopite from Madagascar, also a specimen of manganese ore from Western Australia.

STREATFEILD, H., ESQ.—A specimen of fossil wood from the Lower Greensand, and ammonites from the Lower Gault, of Covers Brickyard, Westerham, Kent.

WHITE, FRANKLIN, ESQ., M.I.M.M.—A series of specimens of villamaninite, etc., from the Providencia Mine, Leon Province, Northern Spain.

WIGG, CARLOS, ESQ.—Two specimens of manganese ore from the Wigg Mining Estate, Minas Geraes, Brazil

WIGHT, MISS.—Specimen of banket from South Africa.

WILLIAMS, C. J., ESQ., I.S.O.—Iron ore of Ordovician age, containing bituminous matter, from Llandegai, Bangor, North Wales.

WILSON, H. A., ESQ.—Specimens of vogtite from a steel-furnace slag

WILSON, H. W., ESQ., B.A.—Casts of footprints of *Iguanodon* from the Wealden (Hastings Beds) of Galley Hill, Hastings.

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TABLE I

STATEMENT showing the NUMBER of GEOLOGICAL MAPS and SECTIONS issued by the ORDNANCE SURVEY to AGENTS, etc., during the year ended 31st December, 1921.

Particulars.	United Kingdom.	England.	Scotland.	Total.
TWENTY-FIFTH-INCH TO THE MILE MAP OF THE BRITISH ISLES :—				
Colour-printed	771	—	—	771
QUARTER-INCH TO THE MILE MAPS :—				
Colour-printed	—	1,034	78	1,112
ONE-INCH TO THE MILE MAPS :—				
Whole-sheets, Hand-coloured :—				
Solid	—	102	156	258
Drift	—	51	4	55
Colour-printed :—				
Solid	—	—	62	62
Drift	—	—	368	368
Uncoloured	—	2	—	2
Quarter-sheets, Hand-coloured :— (Old Series)				
Solid	—	537	—	537
Drift	—	97	—	97
Quarter-sheets, Colour-printed :— (New Series)				
Solid	—	268	—	268
Drift	—	1,877	—	1,877
SIX-INCHES TO THE MILE (COUNTY) MAPS :—				
Whole-sheets, Hand-coloured	—	153	84	237
Uncoloured	—	2	—	2
Quarter-sheets, Hand-coloured	—	117	16	133
Uncoloured	—	762	115	877
Horizontal Sections	—	117	5	122
Vertical Sections	—	105	10	115
TOTAL	771	5,224	898	6,893

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1921

I.—INTRODUCTION

By J. S. FLETT, M.A., D.Sc., LL.D., F.R.S.

In the London district Mr. Dewey and his staff have completed the mapping of the Dartford Sheet (271) and furnish particulars regarding the overlap of the lower Tertiaries in that district and the nature of the underlying surface on which the Eocene beds were deposited. The usual difficulties have been met with in defining the nature, extent and origin of the clay-with-flints which rests upon the surface of the Chalk.

In the West Midland district Mr. T. C. Cantrill and his staff have been engaged in mapping a great variety of formations varying from the pre-Cambrian to the Keuper Marls. The structure of the Silurian inliers on the margins of the Shrewsbury and South Staffordshire coalfields, hitherto somewhat obscure, has been elucidated by the observations of Mr. Wedd and Mr. Whitehead, who find that, in addition to considerable folding, there is a complicated system of faults not directly observable but to be inferred from the exposed outcrops.

Of the Carboniferous rocks of this district the most widespread are the red Upper Coal Measures which contain no workable coal seams, are comparatively unfossiliferous, and consequently are not easily correlated or assigned to definite positions in the stratigraphical sequence. These beds overlie the workable coals, and estimates of their thickness and of their horizon are consequently often of importance. It has been decided to discontinue the use of the term Hamstead Beds for the uppermost members of the sequence (as it might lead to ambiguity), and to substitute the term Enville Beds, which is free from objection. It is still uncertain how far there are strata of true Permian age in those parts of the West Midlands that have been revised on the six-inch scale.

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In the Lancashire district Mr. Wright and his staff have begun the revision of Sheet 76 (Rochdale), which includes part of the northern margin of the Lancashire coalfield. The geology though apparently of a simple type is really more complicated than would be imagined at a first glance. Yoredale rocks (Pendleside series) and Lower Coal Measures occupy most of the country and include four beds of grit which are separated by shales. The identification of the grits in various parts of the district, and their correlation, are being carefully studied as there is an important set of faults bringing various horizons sharply against one another. Several coal seams exist in this series, the principal being the Arley Mine, and since the original geological survey was made a good deal of mining has been done, usually at no great depth. The physiographic features of the district are interesting, as parts of it apparently have not been glaciated and a thick covering of rotted debris or "head" covers the surface of the grits on many of the higher moors.

The report on the mapping of the Cumberland district by Mr. Smith and his staff contains several points of interest. They have been working in two districts, one near Whitehaven, where the principal coal mines occur, and the other north and west of Carlisle. The Whitehaven coalfield is known to be intensely faulted and the thickness and sequence of the beds are variable, and are not completely known; much caution accordingly is necessary in drawing conclusions regarding the geological structure, Mr. Dixon, however, has arrived at an interpretation of the succession in the Carboniferous Limestone that is in accordance with the work of previous observers. Much study has been devoted to the records of bores and the mining plans, to which access has been freely permitted, and the sequence, though variable, has been elucidated in its main features. It seems probable that the Upper Red Measures (represented by the Whitehaven Sandstone) rest unconformably and transgressively on the productive measures, and are in turn unconformably overlain by New Red Rocks.

Both in the Whitehaven and in the Carlisle districts the New Red (including the well-known St. Bees Sandstone) is of great importance. These beds are almost unfossiliferous, though at their base a magnesian limestone occurs that contains mollusca of Permian types; and the question is by no means settled whether the breccias, red sandstones and marls are all to be assigned to one geological period or include representatives of the Triassic system in addition to the Permian.

The glacial geology of North Cumberland is exceedingly complicated, and the mutual relations of local ice-sheets and the larger body of ice that invaded the district from the Irish Sea (ultimately in large part of Scottish origin) are often difficult to unravel. Mr. Dixon furnishes a very interesting account of the conditions at a late stage in the Glacial period in the neighbourhood of Ennerdale where temporary lakes were held up by dams of

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ice and fans of deposit were laid down by streams entering the lakes from the hills on each side.

The Solway raised beaches and river terraces have also received careful investigation. They are of slight elevation (the highest being about 33 feet above H.W.M.), and contrast rather strongly with the raised beaches of Galloway and the Firth of Clyde, which rise to heights of 100 feet. The relations of these beaches to the glacial phenomena, and the exact period of their formation, remain still to be defined.

In Northumberland Mr. Carruthers and his staff have surveyed a large area in the extreme north of the county. The strata are of Lower Carboniferous age (with the exception of the Cheviot lavas, which are Lower Old Red Sandstone) and form a very interesting transition from the Cementstones and Calciferous Sandstones of Scotland to the Carboniferous Limestone type of the Pennines. At the base there is a well-marked Cementstone (Tuedian) Group, which is estimated to form a series not less than 2,000 feet thick, and is well seen in Tweedside above Berwick. Above this is the great Fells Sandstone, a well-marked and characteristic horizon. The Scremerston Coals succeed, and contain from four to seven coals of rather inferior quality. Mr. Carruthers holds that there are large reserves of these coals that may yet prove of commercial importance. The Limestone Group of North Northumberland is equivalent to the Lower Limestones of Scotland, together with practically the whole of the Oil Shale Group of that country. The excellent work of Mr. Gunn, who mapped these rocks for the original survey, has been generally confirmed by the revision, but a careful study of the lithological and palæontological features of the individual beds is being made and as a consequence several changes in the mapping have proved necessary, some of them having an important economic bearing.

In Scotland, Mr. Bailey and his staff have continued the revision of the Ayrshire coalfield and have introduced some important changes in the maps of that district. The lavas of Millstone Grit age near Tarbolton have been proved to have a more extensive outcrop than was hitherto suspected, but the valuable Ayrshire Bauxitic Clay which accompanies these rocks in North Ayrshire has not yet been found in a workable state on the south side of the Kilmarnock coalfield. The north edge of the concealed coalfield of Central Ayrshire is shown to have a very complicated structure, and the relations of the New Red Sandstone lavas and sediments to the underlying Coal Measures are being carefully scrutinised.

The revision of the Central coalfield is now completed, and the 6-inch maps are either published or in the press. The rocks surrounding the coalfield are now being surveyed, and the maps of the outlying coalfields of Muirkirk and Douglas are undergoing revision. Starting from the underlying platform of Silurian and Old Red Sandstone rocks, Mr. Wilson has commenced

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the mapping of the Calciferous Sandstones and Carboniferous Limestone of the Muirkirk field. He has noted also the extensive deposits of glacial sand and gravel which are a conspicuous feature of this district and are to be assigned to the action of the waters discharged from melting ice-sheets at a late stage in the Glacial period. Temporary glacial lakes were formed at various elevations and drained south-eastwards into the Douglas valley by a well-defined series of overflow channels. The Douglas basin, though small, is exceedingly complicated in structure, and contains valuable coal seams. Numerous bores are being made in search for coal, and have been examined and reported on in previous "Summaries of Progress." The revision of this area was started before the war, and is now being resumed.

The Stirling and Alloa coalfields, which link the Central coalfield with that of West Fife, are being re-examined under Mr. Macgregor as District Geologist. Mr. Read has found reason to believe that the Abbey Craig sill is intruded into the Limestone Coal Series, and beneath it there is a considerable thickness of the Lower Limestones. This sill in a district four or five miles to the south-west is believed to be at a horizon about 600 feet lower. The revision of the Alloa and Clackmannanshire coalfield is making progress, and the lower portion of the Coal Measures sequence is now more adequately understood.

The only bore in search of oil under the direction of the Petroleum Department which is now being actively prosecuted is at D'Arcy in Midlothian. It starts near the base of the Scottish Carboniferous Limestone and penetrates rocks of Calciferous Sandstone age, including the oil-shale measures of the Lothians. This series had not hitherto been much explored by borings on the east side of the Dalkeith coalfield, and the bore is consequently of considerable interest from a purely geological standpoint, apart from its importance as a test of a well-marked anticlinal structure and a possible source of liquid petroleum.

In the West Highlands Mr. Bailey and his staff were engaged during part of the year in mapping the metamorphic and igneous rocks of Ardnamurchan and Coll. The Tertiary volcanic mass of the Ardnamurchan peninsula has a most complicated structure, and not more than one half of it has yet been examined by the Survey. It proves to have many points of resemblance to the central area of igneous rocks in Mull. The island of Coll consists of Lewisian sedimentary and igneous gneisses, of which the latter seem to be clearly intrusive into the former. An outcrop of the Raasay Ironstone has been observed at Kilchoan, in Ardnamurchan, but, like all other outcrops of this seam except those in Raasay, there is little prospect that it will prove of economic value.

A large area of metamorphic rocks in Sheet 102 (Lairg), principally of regular Moine types, has been surveyed during the summer months by Mr. Macgregor and his staff. Into this series there have been intruded dykes of lamprophyre and several

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masses of granite, the latter showing occasionally at their margins that they have permeated and in some measure absorbed the surrounding schists. Hornblendic rocks also occur, presumably of igneous origin, and a mass of scyelite or allied rock has been reported near Loch Shin by Mr. Ross.

II.—FIELD WORK

(A)—ENGLAND AND WALES

1. London and South-Eastern District

H. Dewey, District Geologist.
R. L. Sherlock, D.Sc., A.R.C.Sc.
C. E. N. Bromehead, B.A.
H. G. Dines, A.R.S.M., A.M.I.C.E.
} Geologists.

During the early months of the year Mr. H. G. Dines was engaged upon the revision of the Tungsten and Manganese Ores Memoir. He visited the mines where these ores are raised in Cornwall, Devon and North Wales. In the autumn Mr. Dewey visited Cornwall in order to bring up to date the information regarding certain of the tungsten mines. The MS. for the third edition of this memoir is in an advanced stage.

Messrs. Wilson, Eastwood, Pocock, Wray and Robertson were engaged upon the revision of the memoir dealing with Barytes and Witherite. All the mines and workings were visited. The third edition is now passing through the press and will shortly be published.

In the London District the mapping has been continued in Sheet 271 (Dartford). Mr. Bromehead surveyed the Chalk area and the underlying beds in Kent, and Mr. Dines the Tertiary beds and the Pleistocene formations of a small part of Essex. The survey of this Sheet is complete.

Dr. Sherlock was engaged for a few weeks in finishing the survey of Sheet 239 (Hertford). He mapped a small, but economically important, area in the Lea valley north of Waltham Cross.

CRETACEOUS

Mr. Bromehead finds that in the area shown in the south-eastern corner of the Dartford Sheet, which includes a part of the Chalk escarpment of the North Downs, the oldest stratum exposed is the upper part of the Folkestone Beds, the topmost division of the Lower Greensand. It consists of yellow sands with some seams markedly glauconitic and others cemented by silica or lime. The well-known Ightham or Oldbury stone is a glauconitic band thus cemented. The siliceous or cherty beds show hollows usually regarded as casts of sponge spicules, but a calcrete band at Parson's Corner, near Birling, is found to be a felt of small spines belonging apparently to echinoderms. The

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junction of the Folkestone Beds and the Gault clays is abrupt, the base of the latter being a glauconitic bed full of phosphatic nodules. These nodules render the boundary easy to trace in the field, in contrast to that between the Gault and the Lower Chalk, which is a gradual passage, frequently traceable only by the downward limit of lime-loving plants such as *Clematis* and *Campanula*. The Gault is not on the whole fossiliferous; in a deep pit near Paddlesworth belonging to the Portland Cement Companies no fossils were detected. The basement bed and the clays immediately above it have, however, yielded both *Douvilleiceras mammillatum* and *Hoplites*.

The Upper, Middle and Lower divisions of the Chalk have been mapped, usually with some certainty, along the escarpment and in the deeper valleys which dissect the dip-slope. Both lithological and palæontological evidence is available for this purpose; the base of the Middle Chalk is marked by a hard nodular band, the Melbourn Rock, below which lies the soft Belemnite Marl, some 18 inches thick. In the great chalk pits near Snodland the marked contrast between these two beds makes the limit between the divisions very clear. In the mouth of the Medway Gap the Middle Chalk gives rise to a subsidiary dip-slope and escarpment, whereas further west the whole Chalk formation forms a single topographic feature of this nature. It has been remarked by Mr. Hilaire Belloc that the Pilgrim's Road ndicates roughly the upward limit of cultivation towards the chalk scarp. The prehistoric trackway is for the most part, in this district, on the Melbourn Rock, cultivation being practically confined to the more marly Lower Chalk.

The base of the Upper Chalk is also clearly indicated. The *Reussianum* fauna has been detected in every exposure of the horizon, and the Chalk Rock type of sedimentation can be traced throughout the district, since fragments of the hard nodular chalk are scattered over open down-land, wooded belts and arable areas. The zones present in all exposures have been determined, the fossils collected being submitted to Mr. Chatwin. Mr. Osborne White has discussed the distribution of the zones over much of the area surveyed[1]; the new work amplifies but is nowhere discordant with his conclusions.

TERTIARY

The Tertiary beds are not of themselves of great interest, but important facts as to their relationship with each other and with the Chalk have been established. In the north-eastern part of the area the whole series up to the London Clay is present in the Shorne outlier. Much of this ground is heavily wooded, rendering the exact boundaries difficult to define; while the absence of contours and levels on the six-inch maps makes estimates of thickness precarious. The Thanet sands are certainly thinner on the south side of the outlier than they are further

[1] *In* 'Ightham—the Story of a Kentish Village,' by F. J. Bennett, 1907, Appendix II., pp. 119–126.

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west; the Woolwich Beds are apparently normal, the shell bed being exposed at the side of Watling Street—a little to the west of St. Thomas's Well, and on the flanks of the *Oppidum* in Cobham Park. The Blackheath Beds are of the usual pebbly type and at least 20 feet thick, in marked contrast with the poor development at Swanscombe. At Soulers Hill the Blackheath Beds are fossiliferous and yield the characteristic *Pectunculus plumsteadiensis*, Sow. At Cobham Hall the Thanet Sand does not exceed 40 feet; at Cobhambury Wood there is a small outlier, capped by Woolwich Beds, in which the Thanet Sand is only some 10 feet thick. Further south, at Camer, Meopham, Ridley and Ash we find small outliers of Woolwich Beds resting directly on the Chalk. Still nearer the scarp there are outliers of Blackheath Beds at Holly Hill, Stansted and Knockmill again resting directly, as far as can be ascertained, on the Chalk. It is, therefore, clear that in this district, as in that a few miles to the west,[1] there is a true overlap of the Thanet Sand by the Woolwich Beds, and of the latter in turn by the Blackheath Beds. The dip-slope of the Chalk must have been in existence at the beginning of Eocene times, but there is also some new evidence to show that the Chalk had been thrown into minor folds before this plane, on which the successive members of the Eocene system rest, was cut. This pre-Eocene surface is approximately that on which the Clay-with-flints lies. The deposit to which that name is given consists, everywhere in the district, to a large extent and sometimes almost wholly, of Tertiary debris. In fact the distinction between Tertiary beds in place and Clay-with-flints is somewhat vague. Where the Tertiary material is much disturbed, or is a mixture of two or more divisions, it has been mapped as Clay-with-flints, but where a recognisable division, with indications of the original bedding, is visible, an outlier is shown on the map. The boundaries of these outliers are usually uncertain; a hillock rising above the general level may be composed of clean Woolwich Beds, as at Ridley, but it fades off gradually into the thin layer of resorted material with which relics of other beds of Eocene date, chalk-flints, and other components are merged. Owing to the paucity of sections some outliers which ought to be shown on the map may have escaped detection.

The surface of the Chalk falls gradually from the escarpment, where it is about 700 feet above O.D., to the Thames, but the dip of the beds is in the same general direction at a slightly higher angle. At the escarpment the Clay-with-flints rests for the most part on the Zone of *Holaster planus*, often on the *Reussianum* band. The Zone of *Micraster cortestudinarium* comes on about the latitude of Stansted, that of *M. coranguinum* towards Ash and Meopham Green. In the south-east corner, however, these higher beds come on at the escarpment. Near Trosley Towers only the *Reussianum* band is present; the pits

[1] 'Summary of Progress' for 1914 (*Mem. Geol. Surv.*), 1915, p. 28.

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at the southern edge of Whitehorse Wood show at least 35 feet of the *H. planus* Chalk, while the road-cutting north of Birling Place includes a considerable thickness of the *M. cortestudinarium* Zone and the Holly Hill outlier of Blackheath Beds probably rests on the *M. coranguinum* Chalk. This on-coming of higher zones as the Medway is approached suggests that the syncline in which that river flows was at any rate initiated in pre-Tertiary times.

Dr. Sherlock notes that between Hoddesdon and Enfield Lock, in the Lea Valley, a marked difference is noticeable between the two sides of the valley. The west side is mantled by glacial and river deposits down to the alluvial flat, but on the east side the London Clay crops out and drift is only met with about 2 miles back from the alluvium. On this side the country is broken into hill and dale, in marked contrast to the usual flat London Clay topography. Boulder clay caps the hills, about 200 feet above river level, and it is clear that there has been considerable erosion since glacial times.

The difference between the two sides of the valley has an economic aspect which does not seem to have been sufficiently appreciated. The Lea Valley is the chief centre in this country of nursery gardens, which cover a large part of the river brick-earth and gravels, and they obtain an ample supply of water from shallow wells on the west of the valley. The industry is still expanding and many of the new nurseries are built on the east side, on London Clay. In these cases the large firms obtain water from deep wells sunk to the Chalk, but others are dependent on rainwater collected from the roofs and this supply is liable to fail in a dry season.

PLEISTOCENE

Mr. Dines reports that in the neighbourhood of Grays, Essex, there are several sections which show the relation between the Coombe Deposits[1] and the Thames valley gravels. Coombe Deposits and Flood-plain gravel can be seen in the new cutting south of the Portland Cement Company's quarry south of Belmont Castle, and west of Grays Thurrock. At the northern end of the cutting, 10 feet of hard cemented rubbly chalk, the type of Coombe Deposit known as Coombe Rock, rests on the Chalk, but as all the overburden has been removed from the chalk quarry, its former northerly extension cannot be ascertained. Its southern boundary, which trends nearly east and west, forms a cliff about 170 yards north of Askew Farm. Resting against and partly undercutting this cliff is a deposit of dark-brown sand and clay extending along the cutting as far as Askew Farm. Where it rests against the Coombe Rock it consists chiefly of sand, which is locally stratified, containing a few thin beds of pebbles and sub-angular flints. These can

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, pp. 8, 9.

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be traced down to about 3 feet below the surface. Farther away from the Coombe Rock it is more or less stoneless and composed of a much disturbed mixture of sand and clay, and is about 8 feet in thickness. This deposit rests on a homogeneous, coarse, light-coloured sand, which is exposed only in parts of the cutting. The gravel of the Flood-plain terrace appears to be banked against a 3-foot cliff of this Coombe Deposit.

Half-a-mile west of this locality another section of Coombe Deposits can be seen in a cutting leading to a disused quarry belonging to the Thames Valley Portland Cement Company Here the Coombe Rock is banked against a sloping cliff of chalk and appears to be a scree. It is about 20 feet thick and 24 yards broad. Its northern boundary lies at a natural slope, on which there rests a deposit of buff, sandy, almost stoneless, brickearth.

East of the road 500 yards east of Askew Farm, and 300 yards south of the South Essex Waterworks, a small patch of Coombe Rock was removed in October to uncover the Chalk for quarrying purposes. The thickness of it was only 4 to 5 feet; the rest of the Coombe Deposits is also very thin and probably does not extend to the south of the exposure.

In the low cliffs west of the village of East Tilbury, 8 to 10 feet of Coombe Deposits overlie the Chalk. Gravel is much mixed up with the chalk rubble and the deposit in places becomes a true gravel, possibly derived from the outlier of the 50-foot terrace gravel which lies to the north of the section.

2. Shropshire and Staffordshire District

T. C. Cantrill, B.Sc., District Geologist.
C. B. Wedd, B.A.
R. W. Pocock, B.Sc.
T. H. Whitehead, M.Sc., A.R.C.Sc.
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} Geologists.

In Shropshire Mr. Wedd has begun the re-survey of the western end of the Shrewsbury coalfield and has advanced eastward from the neighbourhoods of Wollaston and Westbury in the Welshpool Sheet (151) towards Hanwood in the Shrewsbury Sheet (152). In the Wem Sheet (138) Mr. Pocock has mapped a large area east and south of Hodnet, and also a narrow belt of ground along the western margin of the Stafford Sheet (139). In the Shrewsbury Sheet (152) Mr. Cantrill has continued his examination of the valley of the Tern between Wellington and the county town.

In South Staffordshire Mr. Whitehead has surveyed an area extending eastward from Wombourn in the Dudley Sheet (167) to the neighbourhood of West Bromwich and Handsworth in the Birmingham Sheet (168), while an irregular tract in the southern portion of the latter Sheet has been mapped by Mr. Robertson in continuation of the work already done by Mr. Eastwood.

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PRE-CAMBRIAN

Of the ancient rocks of the Longmynd, upon which the Coal Measures rest to the south-west of Shrewsbury, nothing has been seen but a small tract of dolerite, intrusive in pink felsite, noted at Plealey by Mr. Wedd.

ORDOVICIAN

During his examination of the Bala rocks that bound the Shrewsbury coalfield at the north-eastern end of the Breidden Hills, Mr. Wedd had the advantage of the company of Prof. W. W. Watts, who has more or less completely correlated the Lower Bala sequence seen there with the corresponding series of Caradoc and Shelve. It appears that only the lower half (Caradocian) of the Bala is present, followed unconformably by strata of Upper Llandovery age, not exposed within the area mapped.

The lowest strata seen in the Bala succession, which consists essentially of shales, crop out in the bank of the Severn below Bausley Hill, where they contain pale ashes and a bed of black fine-grained grit. At a higher horizon the attenuated dolerite sill of Breidden Hill dies out eastward; and still higher the mass of fossiliferous ashes, which, with its included conglomerates of igneous material, continues the ridge of Middletown Hill, diminishes north-eastward in Bausley Hill, beyond which it appears to be cut off by one of a group of three faults that trend north-eastward. In the upper part of the sequence a small group of thin limestone-bands and thicker calcareous sandstone has been noted, in which the characteristic *Trinucleus* is *T. concentricus*, as determined by Mr. J. Pringle.

These Bala beds, with strong south-easterly dip, which locally becomes vertical or even inverted, crop out in the north-western limb of the great syncline of Long Mountain, of which the Ludlow and higher rocks occupy the trough. But the general north-eastward strike of the Bala rocks changes to east and even to south-east in the proximity of the faults above-mentioned.

SILURIAN

At the western end of the Shrewsbury coalfield, Mr. Wedd finds that the Tarannon and Wenlock Shales, like the Llandovery strata, are not exposed near Wollaston; but farther to the south-east the Wenlock beds are seen here and there in the south-eastern limb of the Long Mountain syncline, south-west of Westbury. They consist of shales and silty micaceous shales, in which at a high horizon calcareous nodules occur in several beds at Knolls Coppice. Graptolites are found at one or more levels; but these have not yet been determined, nor have the Wenlock beds been adequately searched for fossils.

The scanty exposures of the Ludlow rocks in the north-eastern end of Long Mountain suggest that the bulk of them consists of

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fine quartz silt, so well laminated as to have a shaly appearance. Fossils of characteristic Ludlow species have been found at several horizons; but in the highest beds re-surveyed, some distance below those assigned to the Old Red Sandstone on the published map (O.S. 60 N.E.), a silty sand-rock full of *Lingula cornea* J. de C. Sow. has been observed. This is indistinguishable in lithological character and fossil-contents from a bed assigned by Mr. T. H. Whitehead to the Downton Castle Sandstone in South Staffordshire, as Mr. Pringle noted on comparing specimens from the two localities. But the presence of Downtonian beds characterized by that *Lingula* below the Old Red Sandstone of Long Mountain had previously been recorded by Professors Lapworth and Watts.[1]

On the western side of the South Staffordshire coalfield the survey of the Silurian rocks of the Sedgley neighbourhood has been completed by Mr. Whitehead as far north as Ettingshall Park Farm.

North of Bilston Street, Sedgley, these rocks form a syncline pitching to the south, and well marked by the outcrop of the Aymestry Limestone. The Upper Ludlow beds (with *Chonetes striatella*, *Camarotoechia nucula*, *Goniophora cymbaeformis*, *Orthoceras bullatum*, etc.) in this syncline were well displayed in excavations made on a building-site just north of Bilston Street. These Upper Ludlow beds are overlain by coarse grits and sandstones of the Middle Coal Measures, which occupy the middle of the syncline. It is considered unlikely that Silurian strata higher than the Upper Ludlow can occur under these Coal Measures.

South of Bilston Street the synclinal axis is replaced by an anticlinal axis almost on the same alignment. It is believed, therefore, that a nearly east-and-west fault crosses the area. The anticlinal axis produces a broad outcrop of the Aymestry Limestone, which, in quarries north and south of Catholic Lane, may be seen dipping respectively at about 10° to the west, and at a low angle to the east. Farther south, at Modenhill, the easterly dip has increased to 20°. There is here, however, no trace, in the Aymestry Limestone, of the western limb of the anticline, and Upper Ludlow Shales (with *Chonetes striatella*, *Camarotoechia nucula*, etc.), dipping westwards, appear to abut directly against the easterly-dipping Aymestry Limestone. It is considered, therefore, that a short distance south of Catholic Lane, the anticlinal axis is replaced by a fault.

Another cross-fault, a little south of Cotwall End and Modenhill, throws down the 'Red Downtonian' (Ledbury Passage Beds) on the south against the Upper Ludlow beds to the north. The outcrop of these Red Downtonian beds extends southwards into Ellowes Park, and they are exposed in the stream-section

[1] 'The Geology of South Shropshire,' *Proc Geol. Assoc.*, vol. xiii (1893–4), 1894, pp. 328–9; 'Geology in the Field (Shropshire),' pt. iv., 1910, p. 760.

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referred to in the 'Summary of Progress' for 1920 (p. 12) and also in another stream 150 yards farther north. They have been described by Messrs. King and Lewis,[1] who considered that they form a complete anticline and dip both to the west and to the east under the Coal Measures (*op. cit.*, Fig. 2, p. 93). Observations made during the present survey, however, necessitate a modification of this view of the structure. On the east side of Ellowes Park there was found a small exposure of Upper Ludlow beds, dipping to the east. The Red Downtonian beds can be traced to within 20 yards or less of this exposure, in the stream-section along the northern boundary of Ellowes Park. About a quarter of a mile farther north, greenish sandstones, with a spine of *Onchus* (probably Downton Castle Sandstones), were found a little above the foot of the steep bank along which runs the drive to Ellowes Hall. It was ascertained by boring that the outcrop of the Red Downtonian beds extends to the foot of this bank. It seems clear therefore that a fault, throwing down to the west, must pass near the foot of the bank and along the east side of Ellowes Park.

West of the anticline in the Aymestry Limestone above referred to, the Upper Ludlow beds are overlain by Coal Measures sandstones, dipping to the west. Farther west a narrow strip of Silurian rocks is faulted in. The most northerly exposure in this strip occurs in a ditch about 100 yards north of Ladymore Road. Here nodular and flaggy limestones, and calcareous mudstones (with *Chonetes striatella*), dip at about 60° to the west. Similar Upper Ludlow beds are dug up in the burial-ground and in the fields farther south. At the southern end of this strip, at Cotwall End, Downton Castle Sandstones (identified by Messrs. King and Lewis[2]) overlie the Upper Ludlow beds.

East of the anticline in the Aymestry Limestone a shallow syncline brings in another outcrop of Aymestry Limestone, as evidenced by numerous fragments in the fields near Turlshill House. The continuity of this outcrop with that of Beacon Hill is probably somewhat broken by the cross-fault near Bilston Street.

The Wenlock Limestones and Shales are exposed at Hurst Hill in the form of a broken pericline, on the eastern side of which both bands of limestone crop out. West of the fault the upper band of limestone emerges south of Bilston Street; but north of that street the limestone does not appear on the surface on this side of the fault. It has, however, been mined underground between Beacon Hill and Cinder Hill. Some exposures of Lower Ludlow Shales in holes caused by subsidences yielded *Phacops vulgaris*, *Dalmanella elegantula*, *Bilobites biloba*, *Cyrtia exporrecta*, *Pleurotomaria lloydi*, etc.

[1] W. W. King and W. J. Lewis, 'The Downtonian of South Staffordshire,' *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv., pt. 2, 1917, p. 92.
[2] *Op. cit.*, p. 92.

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The fault that traverses the Hurst Hill pericline probably extends northwards to the neighbourhood of Sedgley Park. Southwards it has been followed to the main road from Sedgley to Tipton. Between this road and Hurst Hill Wood it throws down the Coal Measures on the east against the Silurian (Lower Ludlow) on the west.

The changes in the direction of apparent vertical throw shown by this fault are probably due to the fact that the more important component of the movement was horizontal rather than vertical. It is possible that the fault is a continuation of the one that similarly traverses the pericline of Mons Hill and the Wren's Nest.

CARBONIFEROUS : COAL MEASURES

It had long been surmised that the Middle Coal Measures were not represented in the Shrewsbury coalfield, where the occurrence of a Spirorbis limestone in the coal-bearing strata had been known for many years. Mr. Wedd's re-survey of the western part of the coalfield during the past season has proved that, at any rate as far eastward as Hanwood, Middle Coal Measures are entirely absent from its exposed area, and that only those higher groups are represented which have been classed in North Staffordshire and elsewhere as Upper Coal Measures.

The descending sequence in the western part of the Shrewsbury coalfield is as follows :—

	Denbighshire.	North Staffs.
Breccias : reddish-purple, calcareous, containing a large proportion of Carboniferous Limestone material; sandstones, reddish-purple, more or less pebbly (Alberbury Breccia)		
Sandstones : red, purple, and lavender, some of the more massive in the upper part being pebbly; purple shales; occasional thin bands of quartz conglomerate - - - - - - -	Erbistock Beds.	Keele Beds.
Shales : chiefly light-grey, but with subordinate red shales and purple mottled clays; pale-grey or white sandstones; in the lower part two or three coals, and at least two bands of Spirorbis limestone, one being at the base. Thickness 400 feet or rather more - - - - - -	Coed-yr-allt Beds.	Newcastle Beds.
Clays and marls : purple and mottled, with at least four bands of purple limestone, the highest only 2 feet below the Spirorbis limestone at the base of the overlying Newcastle Beds ; the lowest 5 feet or 6 feet rubbly and calcareous (resting unconformably on purple-stained Bala beds in Braggington Brook). Thickness represented, about 20 feet - - - - -	Ruabon Marls.	Etruria Marls.

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The whole sequence is here assigned to the Upper Coal Measures in accordance with the classification adopted on recent maps of the Geological Survey for the North Staffordshire and other Midland coalfields. Dr. Kidston, however, on palæobotanical grounds, regards only the Keele Series ('Permian' of the old maps), with possibly higher Carboniferous beds such as the Alberbury Breccia, as belonging to the Upper Coal Measures of the Continent; and relegates the two lower divisions to a Staffordian or Transition Series intermediate between Middle and Upper Coal Measures.

Only the topmost beds of the lowest division (Etruria or Ruabon Marls) are present at the outcrop in the western part of the Hanwood coal-district, and these have been detected at only two localities, viz., in Braggington Brook and in a stream west of Westbury. But the similarity both in lithological character and in colour of the remaining sequence (exclusive of the Alberbury Breccia at the top), and the identity of certain details, establish a correlation with the corresponding divisions of the Upper Coal Measures in Denbighshire and North Staffordshire. The more important details of resemblance are the presence of thin limestone-bands in the highest beds of the lower red division (Etruria Marls), and of two at its junction with the overlying pale-grey beds, the upper of these two usually containing *Spirorbis* or entomostraca; the recurrence of more thin limestones, including a second Spirorbis band, in the middle division (Newcastle Beds); and the incoming of lavender-coloured felspathic sandstones in the lower part of the upper red division (Keele Beds). Moreover, Dr. Kidston's examination of plants collected by Messrs. Templeman and Hester, chiefly from the lower beds of the middle division, indicates a zonal position higher than the Middle Coal Measures.

Of the above sequence the middle division (Newcastle or Coed-yr-allt Beds) alone contains workable coal-seams, and constitutes the Hanwood coal-district, in which the prevalent pale colour of the measures contrasts with the generally dark colour of Middle Coal Measures shales. It contains in its western half only two or three coals, and these rarely attain an individual thickness of more than two feet, only one of them being as a rule thick enough to work. Coal is now raised in that part of the field in the neighbourhood of Hanwood alone; but in former times it has been worked at several localities westward as far as the extremity of the exposed field, viz., in the districts of Pontesford, Asterley and Westbury, and at Bretchel, Wollaston, Braggington and Coedway.

Besides the transfer of red beds formerly classed as Permian to the Upper Coal Measures, the re-survey has necessitated certain other changes of mapping. At the north-western extremity the outcrops of the several divisions of the Upper Coal Measures do not sweep round in a uniform synclinal curve as represented on the extant map (60 N.E.). The junction of the

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Coed-yr-allt or Newcastle Beds with the Bala is there undoubtedly faulted by one of the north-easterly faults mentioned above, though in Braggington Brook intensely stained Bala beds are exposed on the downthrow side of the fault under the thin remnant of the Ruabon Marls; the upper red division also extends there farther westward than the 'Permian' outcrop as shown on the old map, and is faulted against the Newcastle Beds by another fault of the same group; also there is reason to believe that a southward-trending dislocation on the western side of Alberbury Park cuts out an appreciable part of the Keele Beds below the Alberbury Breccia, the highest member of the Upper Coal Measures sequence of the district.

So far as the work has proceeded, no indication of unconformability has been detected within that sequence.

Around Ollerton, between Wellington and Market Drayton, certain purple marls with thin greyish sandstone bands, shown on the old map (73 S.E.) as Permian, are now referred by Mr. Pocock either to the Keele Beds or to the Etruria Marls. They have a slight dip to the north-west, in which direction they appear to pass beneath the Lower Mottled Sandstone of the Bunter. On the south they are bounded by a fault that passes between Ollerton and Child's Ercall.

The re-survey of the South Staffordshire coalfield has been continued by Mr. Whitehead between the Western Boundary Fault, near Sedgley, and the neighbourhood of Wednesbury and West Bromwich. Mr. Robertson has also mapped a small area between Wolverhampton and Bilston.

A small area of Middle Coal Measures crops out west of Sedgley, near Sedgley Hall and Cotwall End. There are here traces of old open workings in which the Thick Coal is said to have been got. Coal has also been worked underground near Sedgley Hall. This outcrop of Middle Coal Measures is bounded on the west by the Western Boundary Fault, and is probably also faulted on the east against the strip of Silurian rocks mentioned on p. 27.

The Red Downtonian rocks in and near Ellowes Park are, on the west, overlain unconformably by Middle Coal Measures containing two coal-seams. This outcrop is bounded on the west by the Western Boundary Fault. Other areas of Middle Coal Measures near Sedgley have already been alluded to in discussing the Silurian rocks.

At Upper Gornal thick and massive sandstones form a conspicuous element in the lower part of the Middle Coal Measures. These include the well-known Gornal Sandstone, which is quarried to some extent for building-stone, and also as a source of silica sand.[1] These sandstone beds, somewhat diminished in thickness, extend northwards to the Sedgley-Tipton road. To the south-east and south-west of Gornal they diminish rapidly in thickness.

[1] 'Special Reports on Mineral Resources, vol. vi., Refractory Materials' (*Mem. Geol. Surv.*), ed. 2, 1920, pp. 13, 98, 99.

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At three localities, namely, near Parkes Hall (Woodsetton), near The Coppice (Hurst Hill), and about 700 yards north-west of Cinder Hill, there have been found evidences of coarse conglomeratic beds at or near the base of the Middle Coal Measures. At these localities there occur abundant and large pebbles of quartzitic grit, together with fragments of conglomerate and of coarse grit with a ferruginous cement. The presence of such coarse material at these places is of interest in connection with the view put forward by Mr. W. King[1] as to the probable derivation of the materials forming the basal Middle Coal Measures conglomerates from the neighbourhood of the Lickey Hills. Mr. King remarks that at Ellowes Park these basal conglomerates have become one band of coarse sandstone. At the localities mentioned above, however, at equal or greater distances from the Lickey, coarse basal conglomerates still remain. A tentative explanation may be offered which might reconcile this fact with Mr. King's views of the source and distribution of the coarse sediments. It is conceivable that in early Middle Coal Measures times the Sedgley-Rowley-Lickey uplift may have existed as a shoal or bank but little below, or even above, sea-level. Along such a bank coarse shingle might be drifted by tidal or current action to distances farther from its source than in the deeper water on either side.

East of Sedgley the ground is largely covered by buildings and debris, so that little evidence regarding the Coal Measures can be obtained from surface observations. The outcrops of several of the coal-seams can, however, be traced at intervals along the border of the Silurian ground. Near the outcrops the coals are being got in slopes and shallow pits, and the clays associated with the Bottom Coal are being dug in open workings. Away from the crop, mining has almost ceased, owing to flooding. Some trouble has been experienced in the workings near the crop from 'black damp,' which has probably been driven up to this level by the rise of water in the deeper workings.

During the coal strike several seams, including the New Mine and Stinking Coals, were worked at the outcrop south of St. Chad's Church, West Coseley. The measures here have a westerly or north-westerly dip. Considering this in conjunction with the north-easterly dip of the measures off Mons Hill, and of the easterly dip near The Coppice, Hurst Hill, it is clear that the measures lie in the form of an almost complete basin. The central portion of this basin is obscured by material thrown in to restore the level of the ground after the removal of the Thick Coal; but, so far as can be ascertained, the highest beds present consist of the clays of the Ten Foot Measures, which here contain abundant plant-remains.

The Etruria (Old Hill) Marls certainly extend as far west as Horseley Heath, and possibly as far as the canal near Tipton Station. They are probably brought into this position by a

[1] 'The Plexography of South Staffordshire in Avonian Time.' *Trans. Inst. Min. Eng.*, vol. lxi., pt. 5, 1921, p. 164.

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fault, having a downthrow of from 60 to 90 ft. to the south, which runs through Horseley Colliery in a W.S.W.–E.N.E. direction.

At Tibbington beds that seem to be transitional from the Middle (Grey) Coal Measures to the Etruria Marls are seen in a large clay-hole at the brickworks. The clays are mostly of a bluish-grey colour, and are of Middle Coal Measures rather than of Etruria Marl type, though a reddish colour sets in near the top. About half-way up the section there is a coal-seam about 2 ft. thick, which is locally identified as the Two Foot Coal. Another coal about 9 in. thick occurs about 20 ft. higher. At the bottom of the hole, some 40 ft. below the Two Foot Coal, there is a massive gritty sandstone of distinctively 'espley' type. Similar apparently transitional beds were seen at Ocker Hill.

On the western side of the coalfield the outcrop of the Keele Beds near The Straits extends northwards nearly to Cotwall End. They are poorly exposed in The Dingle (600–700 yds. south of Cotwall End), where they lie close against the Western Boundary Fault. It is probable that another outcrop of Keele Beds exists in the neighbourhood of the coal-shaft near Sedgley Hall, faulted on the west against the Enville Beds and on the east against the Middle Coal Measures. The presence at the surface of Keele Beds here is inferred from the section of the shaft,[1] which shows about 120 ft. of red marl with three bands, 2 to 3 ft. thick, of sandstone, followed, downwards, by Middle Coal Measures. So great a thickness of marls, relatively to the sandstones, is more characteristic of the Keele Beds than of the lower portion of the Enville Beds.

On the eastern side of the coalfield Keele Beds probably outcrop over the whole of the area around West Bromwich between the Eastern Boundary Fault and Sandwell Park. Much of this area is drift-covered, but the red and mottled marls, with lenticular sandstones up to 40 ft. thick, of the Keele Beds are exposed in the cutting of the Great Western Railway near West Bromwich Station.

This outcrop of Keele Beds extends northwards to beyond Newton Road, where it is probably terminated by the Eastern Boundary Fault, which is believed to change its direction near Carter's Green and to run from here north-eastward towards Hill Farm near Great Barr.

Enville Beds.—On the western side of the South Staffordshire coalfield the Enville Beds[2] are well developed west of Sedgley, around Gospel End and Sandyfields. Near the latter place the Calcareous Conglomerate Group forms a conspicuous scarp slope facing south-east. Upon this, subsidiary ribs, due to the

[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, p. 182, and Vert. Sect., Sheet 17, No. 21. Another version of the section, the upper part of which agrees with that quoted by Jukes, has been supplied by Mr. W. King.

[2] *See* Appendix VII, p. 169.

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calcareous bands, are well marked, and are usually three in number; though they may be reduced to two or increased to four by the disappearance, or splitting, of one or other of them. Near Sedgley Hall the highest calcareous band, consisting of pebbly calcareous sandstone and conglomerate, dipping north-west at 40°, is succeeded upwards by beds, probably 100 ft. thick or more, composed largely of breccias. These breccias are coarser than any others seen in this neighbourhood, though finer than those near Wordsley and Kingswinford, and much finer than those of the Clent Hills, which they, in other respects, resemble. The stream-sections show that these breccias are followed upwards by a series of bright-red marls and marly sandstones, with 'fish-eyes,' and some beds of green sandstone.

The three calcareous bands, more or less well defined, of the Calcareous Conglomerate Group can be traced over the whole area between Penn Common and Himley Park. They are repeated in places by faults, and the highest band is followed, as near Sedgley Hall, by the Breccia Group, with breccia or breccia-sandstone in the lower portion. Fine-grained breccias can be traced along Penn Brook (south of Penn Common), their continuity interrupted by faults, from near Lloyd House to within half a mile of Hickmerelands Farm. The ground about Penn Common is largely covered by superficial deposits; but the deeper stream-courses to the west and east expose the bright-red marls with sandstones that overlie the beds with breccias. At Alder Coppice, east of Penn Common, a thin fine-grained breccia occurs amongst these marls. Near the Colton Hills these red marls have been worked for brick-making, and an excavation has been made in them immediately at the foot of the Bunter Pebble Bed escarpment.

On the eastern side of the coalfield the Enville Beds occur in Sandwell Park. Here, in an old quarry and in the trenches of some old rifle-butts, there are exposed pink calcareous sandstones, and calcareous conglomerate or breccia. This last contains small subangular pebbles of red and yellow chert. These beds, which have an easterly dip, are considered to lie at the base of the Enville Beds, as no trace of similar rocks can be found farther west. They can be traced northwards to Sandwell Hall, near which they are believed to come against the outcrop of an important fault proved underground in the workings of Sandwell Park Colliery. This fault, which throws down to the east, has the effect of shifting the outcrop of the base of the Enville Beds about a mile northwards, to the neighbourhood of Newton Road Station, near which they were recorded by Mr. Cunnington.[1]

South of Sandwell Park the ground is drift-covered; but the Enville Beds are again exposed in the cutting of the Great Western Railway west of Handsworth and Smethwick Station.

[1] 'Summary of Progress' for 1912 (*Mem. Geol. Surv.*), 1913, pp. 28–9.

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They here include the coarse calcareous conglomerate mentioned by Jukes.[1]

PERMIAN

In the Lichfield Memoir certain breccias that underlie the ordinary conglomerates and pebbly sandstones of the Bunter Pebble Beds and rest usually upon the Enville Beds were described under the name 'Hopwas Breccia,' and assigned with doubt to the Permian system.[2] On the south-eastern side of the South Staffordshire coalfield, near Handsworth, evidence of similar breccias has been found at three places by Mr. Whitehead. Near Manwoods Farm certain of the fields are strewn with angular fragments of grey quartzite, and an overgrown quarry shows traces of red marl and sandstone with some angular fragments. These fragments resemble those described[3] as occurring in the Hopwas Breccia near Sutton Coldfield. In some allotments north of Handsworth Cemetery shallow excavations expose red marls and marly sandstones with thin beds of fine-grained breccia, of which the constituents appear to be chiefly fragments of decomposed and red-stained igneous rock. Similar beds are to be seen in small excavations about a quarter of a mile east of The Austins, on the eastern side of the Sandwell Road. These fine breccias and red marls resemble some beds which, in the canal-cutting near Hamstead, lie unconformably on the Enville Beds, and are believed to represent the Hopwas Breccia.

TRIAS

Of the Triassic strata that abut against the Alberbury Breccia in the western part of the Shrewsbury coalfield little has yet been seen. Mr. Wedd finds that they occupy the low ground that descends to the Severn valley below the dip slope of that breccia, and are not well exposed. They belong to the Bunter division, but their classification in detail and the nature of the boundary between them and the breccia at Alberbury are not yet certain.

Mr. Pocock finds that, south and east of Hodnet, the Lower Mottled Sandstone occupies much of the surface. It is bounded on the west by a fault that brings in the Keuper Marl and Upper Mottled Sandstone of the Hawkstone area.

The Bunter Pebble Beds form a small outlier at Hodnet, bounded on the west by the same fault. They form the higher ground north of Wistanswick, and crop out also around Child's Ercall, Great Bolas, and Shray Hill. Their base is markedly

[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, p. 11. *See also* W. W. King, 'The Permian Conglomerates of the Lower Severn Basin,' *Quart. Journ. Geol. Soc.*, vol. lv., 1899, p. 116, and W. H. Hardaker, 'On the Discovery of a Fossil-bearing Horizon in the "Permian" Rocks of Hamstead Quarries, near Birmingham,' *ibid.*, vol. lxviii., 1912, pp. 652 and 654.

[2] 'The Geology of the Country around Lichfield' (*Mem. Geol. Surv.*), 1919, chap. vi.

[3] *Op. cit.*, p. 123.

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calcareous in places, as in the left bank of the Tern at Great Bolas. At Hungryhatton many silicified logs of wood were found in a small exposure of what appear to be Pebble Beds, and fragments of this silicified wood are common on the surface of the fields in the vicinity; but as the fossilised wood appears to be a Carboniferous species, the beds in question may prove to be some part of the Coal Measures.

The Upper Mottled Sandstone is well exposed in the steep slopes of the Marchamley and Kenstone Hills and in Hodnet Park. At Marchamley Hill it is separated from the Waterstones by about 20 ft. of white fine-grained Lower Keuper Sandstone, which appears to be absent at Kenstone Hill. This white sandstone thickens westwards and is well developed in the Grotto Hill at the western end of Hawkstone Park. From this point its outcrop is shifted nearly four miles to the south-west by the western boundary fault of the Hawkstone area, and where it appears on the west of the fault it forms the well-known building-stone of Grinshill.

The Waterstones attain a greater thickness near Marchamley than at Grinshill. A total of 32 ft. can be seen in the road-cutting at Marchamley Hill.

The Keuper Marl, of the usual red and grey shaly type, is faulted, north of Marchamley, against the Waterstones and Keuper Basement Beds of Hawkstone Park, and occupies a considerable area to the north. It can be seen also east of the Tern, near Stoke Grange, dipping steeply westward, away from the eastern boundary fault of the Hawkstone area.

The area surveyed by Mr. Robertson in the southern environs of Birmingham (Sheet 168) is roughly triangular in outline, comprising the ground extending from the Birmingham Fault eastwards as far as the valley of the Cole, and extending southwards from Aston Manor to about two miles south of King's Norton. The Birmingham Fault runs in a south-west direction from Saltley to Northfield, with downthrow to the south-east. Along this part of its course, except in the extreme south, it appears generally to bring Keuper Marl into contact with Lower Keuper Sandstone at the surface. Within half a mile of the fault the Lower Keuper Sandstone usually gives place to Upper Mottled Sandstone, since the prevailing dip is south-east. On the downthrow side of the fault the dip is also south-east, at a low angle, as shown by exposures at King's Norton, Northfield and King's Heath. The throw of the fault appears to reach its maximum in the neighbourhood of Selly Oak or slightly farther to the north. A boring at Selly Oak Baths passed through more than 400 ft. of Keuper Marl. Farther north, at Saltley, the throw is less, and the sandstone was reached at a depth of about 80 ft. in a boring at the Corporation Gasworks in Duddeston Mill Road. A mile south-west of Northfield, where the fault is cut off by a smaller N.N.W.–S.S.E. fault, the throw has decreased so much that Keuper Sandstone crops out on both sides.

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South-eastwards from the fault the thickness of the Marl gradually increases, and is at least 600 ft. where bored through at King's Heath. Thence it stretches to the east under the Cole valley, and is continuous towards Solihull with that underlying the Forest of Arden.

On the eastern side of the South Staffordshire coalfield Mr. Whitehead finds that the Bunter Pebble Beds constitute the highest solid formation over the greater part of the Handsworth area, though they are almost everywhere covered by drift. Their base is, however, well seen at Hamstead Hill, where they rest directly upon the Enville Beds. About 300 yards west of Handsworth and Smethwick Station, in the railway-cutting, the base of the Pebble Beds is again exposed, resting, as at Hamstead Hill, directly on the Enville Beds.

Owing to the prevalence of drift, the position of the boundary between the outcrop of the Upper Mottled Sandstone and that of the Bunter Pebble Beds, south of Handsworth, can only be conjectured. The former division is, however, exposed under the drift in a sandpit at a salvage depôt of the Birmingham Corporation (formerly the Handsworth U.D.C. Sanitary Depôt) about 600 yards east of Handsworth and Smethwick Station. This place is very much further west than the Upper Mottled Sandstone is represented as extending on the Old Series one-inch geological map (62 S.W.). This evidence corresponds with that found by Mr. Eastwood[1] farther south. It is probable that the fault mapped by him, east of the cemetery, Smethwick, to account for the narrowing of the Pebble Bed outcrop, extends northwards to beyond Handsworth and Smethwick Station.

On the west of the South Staffordshire coalfield the Bunter Pebble Beds crop out from Earlswood southwards to Himley Hall, dipping to the east, and faulted on the east against the Enville Beds. Here they are well consolidated, and consist of massive pebbly sandstones and quartzose conglomerates, in places with a calcareous cement. Small lenticles of calcareous breccia occur in the basal portion. About Upper Penn, on the other hand, the Pebble Beds consist of semi-consolidated pebbly and sandy beds. Here the Bunter Pebble Beds rest directly upon the higher red marls of the Enville Beds.

East of Wombourn the Bunter Pebble Beds are underlain by the Lower Mottled Sandstone, which is well exposed in the stream-course called Rushford Slang, in the grounds of the Wodehouse.

The Upper Mottled Sandstone crops out over the whole area around Wombourn and as far north as Orton, except where it is capped by Keuper. The Basement Beds of the latter occupy the high ground east and south-east of Orton. They consist of reddish-brown pebbly sandstones with lenticles of calcareous breccia. Similar pebbly sandstones were found capping some high ground south-west of Wombourn and just west of the Stour-

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, pp. 18, 19.

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bridge–Wolverhampton road. The discovery here of an outlier of the Keuper Basement Beds is of interest, as it approximately fixes the position of the southerly continuation of a fault, which, near the Lloyd House, throws the Upper Mottled Sandstone and Keuper Basement Beds against the Bunter Pebble Beds.

GLACIAL AND POST-GLACIAL

At the western end of the Shrewsbury coalfield Mr. Wedd has examined some ground drained by the Rea Brook and a nameless confluent, which, rising in Hargreaves Wood, flows eastward by Westbury and Stretton Heath. At Hanwood the pre-Glacial valley of these united streams is constricted by a tough red till composed largely of local material derived from the outcrop of the Erbistock Beds, and there constituting the lowest member of the drift. This constriction of the valley has had a marked effect in holding up the drainage during the melting of the ice-sheet.

The till and higher drifts of looser texture are sufficiently thick to have obliterated the physiographical features of solid rock north of the valley at Hanwood, but are less thick on the rising ground south of it. Farther west also, on the northern side of the valley, the drift diminishes in thickness. On Wattlesborough Heath, in a new well on the northern side of the Shrewsbury road, 22 ft. of tough purple till of similar origin was found to become gravelly in its lower part. This was probably not far above the solid rock; for immediately north of the Heath the rising ground made by sandstones of the Erbistock Beds is bare of Glacial debris. Still farther west the superficial drifts of loose and often rough gravelly material, while completely covering the surface of the Coal Measures (Newcastle Beds) between Halfway House and Wollaston, are not thick enough to obscure the escarpments of sandstones, so that it is possible to trace the outcrops of unseen beds in spite of the drift covering.

Torrential conditions at the close of the Ice Age are exemplified by coarse rudely-bedded gravels derived largely from the Lower Palæozoic rocks of the Long Mountain. In the valley of the stream above-mentioned as a confluent of the Rea Brook, this material was swept off the steep slopes of Ludlow rock and out of rapidly-eroded gorges to form thick gravel-bars, which impeded the drainage and account for the devious course of the present stream for some distance below its source in Hargreaves Wood. The obstruction of the valley lower down at Hanwood caused the formation of small lakes, and in one of these, between Wattlesborough Heath and Halfway House, laminated clays were deposited on a gravel base some 10 ft. or 15 ft. above the present stream. These clays have long been worked for brick-making.

In the southern bank of the Severn below Belan Bank, north of Middletown, Professor Watts and Mr. Wedd have noted glacial striæ on a *moutonnée* surface of dolerite. The striæ indicate a local direction of ice-flow due eastward.

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In the area surveyed by Mr. Pocock much of the ground is free from drift. Boulder-clay of a sandy type occurs south of Hodnet and near Peplow, but is nowhere very thick. The same type of drift is found near Child's Ercall and Eaton upon Tern, as also in the neighbourhood of Great Bolas and Cherrington. Sands, possibly of glacial origin, are seen east of Stoke upon Tern and at Hodnet Heath.

Terraces of sand and gravel occur along the course of the River Tern at varying heights above the alluvium of the river.

In the area to the south of Birmingham Mr. Robertson finds that the drift is, as a general rule, confined to the higher ground. Along the valleys of the Rea and Cole the Keuper Marl is exposed above the alluvium in most places, but is capped by a variable thickness of glacial material, in places clayey, but elsewhere sandy or gravelly.

Around Selly Oak the drift can be roughly divided into a lower group of clays and an upper group of more sandy and gravelly material, as shown by Mr. Eastwood[1] in the California area about a mile and a half farther west.

The Bournville and Cotteridge area is noteworthy for many large erratics. Some of these are preserved on the Cadbury estate at Bournville, and others in Cotteridge Park. Most of them are of Arenig volcanic type, but a few are quartz or sandstone. One Arenig boulder found just west of Bournville Station measures 8 ft. by 7½ ft. by 5 ft., and weighs 9 tons. Similar boulders up to 5 ft. in length are to be found on the south side of the Lifford-Northfield ridge, lying in some cases in the drift and in others on the Keuper Marl slope below it. South of this ridge, as far as West Hill, the country shows rounded marl features free from drift, and no large erratics were seen.

The drift on the high ground between the valleys of the Rea and the Cole can be divided into two parts. South of King's Heath it is mainly clayey in character; but north of this, by Moseley and Sparkhill to Bordesley, it is in the main gravelly and sandy. A tongue of sand and gravel also extends up the left bank of the Cole as far as Trueman's Heath (south-west of Shirley), and may be continuous with the Moseley gravel. The junction between the gravelly and the clayey drift appears to be very indefinite; the gravels and sands, however, come down to lower levels than the clays. They are over 100 ft. thick at Moseley, whereas the clayey drift south of King's Heath rarely attains a thickness of more than 20 ft.

The majority of the pebbles composing the gravels are of quartzite, with smaller numbers of vein-quartz, grit, chert, and conglomerate. Igneous pebbles also are frequent, including some of granite, of quartz-porphyry, and of Rowley basalt. Most of the pebbles are probably of local origin, and can be traced to the Triassic and Carboniferous rocks exposed farther to the west. The far-travelled ones can in the majority of cases be matched

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, p. 22.

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in North Wales, whilst no characteristically Scottish or Lake District erratics occur. The gravel along the left bank of the Cole valley near Yardley Wood appears much richer in grit and conglomerate pebbles than that at Moseley.

In the area around Handsworth mapped by Mr. Whitehead the drift is mostly gravelly in character, but with some admixture of clay and loam.

In the valley of the Tame, west of Perry Barr, the fields a little above the level of the alluvium are abundantly strewn with pebbles. Of these the most common are of quartzite, of Bunter type; but many fragments occur of calcareous sandstone and chert conglomerate of Enville Bed type, and of quartzose conglomerate with a ferruginous cement. These materials probably represent a deposit that should be classed with the late-Glacial gravels found farther north.[1]

At the Birmingham Corporation Salvage Depôt (p. 35), near Handsworth and Smethwick Station, a sand-pit shows about 12 ft. of rudely false-bedded pink and brown sand, with lenticles of gravel and clay, resting on some 15 ft. of pink quartzose sand with rare pebbles. At Park Farm near Handsworth Golf Course another sand-pit exposes about 16 ft. of pebbly sand, loam, and gravel, of which the lower portion shows fairly regular bedding. In a ditch a little to the east of this, and at a lower level, there was found a stiff purple mottled clay with a few pebbles. Red and greenish mottled clays, mingled with sand and pebbles, were also seen in this neighbourhood.

The higher ground of Sandwell Park and Handsworth Cemetery is occupied by sandy and gravelly drift with false and disturbed bedding. Fragments of ferruginous conglomerate, like that seen near Perry Barr, were found in the gravel-pits in Sandwell Park. A bed of this conglomerate was seen *in situ*, interbedded amongst the drift deposits, in the canal-cutting east of Spon Lane.

The valley between Sandwell Park and West Bromwich is free from drift, as is also a small area of the highest ground in the centre of West Bromwich itself. From here the drift extends northwards to the Tame valley near Hill Top, varying in thickness, and consisting chiefly of gravelly materials, but with beds of loam and clay in places. A distinction between bedded and unbedded drift can sometimes be made in the sections, but their similarity in composition renders their separation, away from the immediate neighbourhood of the sections, extremely difficult.

Outlying patches of gravelly or pebbly drift occur at New Town, also between Horseley Heath and Toll End, and again at Ocker Hill. West of these places the ground is free from drift.

West of the South Staffordshire coalfield the drift, in the area surveyed, is confined to three patches of unbedded gravel, with a matrix of red or orange sand, lying at a height of from 310 to 340 ft. above Ordnance Datum, near Wombourn.

[1] 'Geology of the Country around Lichfield' (*Mem. Geol. Surv.*), 1919, p. 190.

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About Penn Common and the neighbouring fields the solid geology is largely obscured by a deposit consisting of red clayey material, mingled with many Bunter pebbles, and with some derived from the Glacial drift. The deposit has very indefinite boundaries, and is believed to be of the nature of talus, rather than boulder-clay in place.

Several erratic boulders of granite and other igneous rocks may be seen in Upper Penn village. One of pink granite lies on Penn Common, and another, of granite or of syenite, was seen near Wombourn. The incised character of the stream-courses about Penn Common and Wombourn is a feature of interest.

3. Lancashire District

Headquarters: Manchester.

W. B. Wright, B.A., District Geologist.
R. L. Sherlock, D.Sc., A.R.C.Sc.
D. A. Wray, M.Sc.
W. Lloyd, B.Sc.
L. H. Tonks, M.Sc. } Geologists.

This unit began its field season in the spring and commenced the re-survey of the Rochdale Sheet (76). Much time was required for the establishment of the new office in Manchester and for getting into touch with the mining and other interests in the district; discussion of the results of this year's field work may therefore be advantageously postponed until the relations of the formations in different parts of the area have been more completely studied.

The district between Ramsbottom and Turton, surveyed by Mr. Wright, is composed partly of Lower Coal Measures and partly of the higher members of the Millstone Grit. Much of the ground is highly faulted, and it is difficult to find sections to establish an undoubted succession. Around Holcombe Hill, however, the strata are undisturbed, and sections are available showing the local sequences from the Rough Rock to the uppermost member of the Third Grit series. The Sand-rock Coal within the Rough Rock is exposed in the quarries along the escarpment above Holcombe. It is about 12 inches thick with a sandstone roof and is underlain by two feet of fireclay resting on the lower division of the Grit. This coal has been traced in the neighbourhood of Turton.

At Holcombe the Haslingden Flags are poorly developed; they rest on grey mudstones, about 100 feet thick, which pass downwards into dark shales with a marine band at the base, overlying a coal about 13 inches thick, the Upper Holcombe Seam. This is well exposed to the north of Redisher Bleach Works and on the opposite side of the valley; it has a fireclay seat about 3½ feet thick which passes down into strong sandy shales with sandstone ribs visible for a thickness of about 15 feet. Below this the section is obscured, but 30 or 40 feet below the

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Upper Holcombe Seam a second seam is poorly exposed in the brook below. It rests on about 4 feet of sandy fireclay with ferruginous concretions, beneath which comes the uppermost bed of the Third Grit.

Binney[1] in his description of this section, which he makes the type section of his 'Holcombe Series,' mentions a third coal seam, 8 inches thick, the 'Middle Coal,' and places it some six feet below the top coal. This seam is not at present exposed in the sections described above, but information from a boring in another locality suggests that it may possibly exist, though it certainly does not lie as near the Upper Holcombe Seam as Binney suggests.

At Edgworth, about two miles west of Holcombe, the Haslingden Flags attain a fine development and have been very extensively quarried.

Dr. Sherlock has commenced mapping around Todmorden and Accrington. Accrington is situated in a synclinal hollow extending in a W.S.W.–E.N.E. direction. About two miles to the south of the town the Lower Coal Measures give place to the Millstone Grit, but the actual junction is often a fault. However, on Haslingden Moor the Coal Measures seem to rest normally on Millstone Grit, although the two are obscured by peat.

At Accrington the Lower Mountain Mine has been, and is still being worked, as well as, to a small extent, the Upper Mountain Mine. About a mile and a half to the east of Accrington, the Middle Coal Measures, with the Arley Mine at the base, crop out on a high moor, and during the recent strike the seam was extensively worked at outcrop. The Middle Coal Measures occupy only a narrow space between a pair of faults.

The Millstone Grit comes to the surface midway between Accrington and Haslingden. In the small area surveyed, round the latter town, the 1st or 2nd Grits and some sandstones below the 2nd Grit crop out, the 3rd Grit not being reached. The 1st Grit, or Rough Rock, has the character of the 4th (Kinderscout) Grit and is a coarse grit with small pebbles of quartz. The Sandrock, or Feather-edge Coal, that divides the Rough Rock, has no commercial value. At Haslingden it is a pockety coal about 18 inches to 2 feet in thickness, interstratified with clay and resting on 18 inches to 3 feet of clay with ironstone. The outcrop of this coal often makes a small surface feature. About 150 feet of strata separate the 1st and 2nd Grits.

The 2nd Grit, locally known as the Haslingden Flags, is worked for setts and flags, and was at one time also used for 'slates.' Enormous quarries near Haslingden prove the former extent of the industry. The rock is a sandstone, not a grit. A faint greenish tint characterises the Haslingden Flags, and the same colour is noticed in the mudstones below. These have often a spheroidal structure. The thick masses of flag are not on a

[1] 'The Lancashire and Cheshire Coal-Field,' *Trans. Geol. Soc., Manchester*, vol. i., 1860, p. 79.

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constant horizon, and pass laterally into shale or mudstone. At Haslingden the sandstone is about 100 feet in thickness.

The physiographic features of the district are of interest. The ground is heavily burdened with Glacial Drift. Accrington itself stands for the most part on boulder-clay, and Haslingden on sand and gravel. Channels cut by waters from the melted ice are seen at various elevations. One channel has been utilised by the high road from Rising Bridge, Baxenden, to the north end of Haslingden. This channel has a floor of peat and is bordered on the west by a large whalebacked ridge of drift.

The present streams flow in deep hollows, or cloughs, and, up stream, in practically every case a small waterfall is reached. Above the falls the valleys are much less deeply trenched than below. It is evident that there has been rejuvenescence of the streams since the Glacial epoch.

Mr. Wray was occupied in the moorlands east and south of Rochdale and Littleborough. Here again the Sand-rock or Feather-edge Coal occurs in the upper part of the Rough Rock; it is well exposed in two quarries at Ogden Edge, where it is about 2 feet thick and under- and overlain by grit.

The Lower Coal Measures attain a thickness of over 1,300 feet in this district, the upper limit being taken at the Arley or Royley Mine Coal, the lowest thick coal of the Middle Coal Measures. They consist of an alternation of shales and sandstones, with several thin coal seams. The beds have a general easterly and south-easterly dip, and are traversed by numerous faults, which for the most part range in a north-westerly direction. The several coals known locally as 'Mines' in ascending order are as follows: the Six-inch Mine; Yard Mine; Lower Foot Mine; Mountain Mine or Ganister Coal; Bullion or Upper Foot Mine; Inch Mine (with an important bed of fireclay underlying it which is being worked in the neighbourhood of Littleborough); and the Forty Yards or Upper Mountain Mine. Along the southerly part of the district the more important Mines have been worked in collieries of considerable depth, but in the north around Littleborough they crop out along the flanks of the moorlands and have been extensively wrought in shallow workings. Except in the neighbourhood of Rochdale, where the Mines occur at a considerable depth, the coals have been largely worked out.

The Six-inch Mine occurs within a few feet of the Rough Rock. It was formerly worked along its outcrop at Binns, near Higher Ogden, where its roof consisting of black shale is crowded with impressions of *Aviculopecten, Goniatites*, &c. This is overlain by sandy shales and flagstones, above which comes a massive sandstone, to which Binney[1] applied the name of 'Woodhead Hill Rock.' This sandstone, 60 to 80 feet above the base of the Lower Coal Measures, is well developed on Shore Moor, to the north of Littleborough, on Whittaker Moor, and

[1] *Trans. Geol. Soc., Manchester*, vol. i., 1860, p. 75.

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on high ground on both sides of the Piethorne valley at Higher Ogden. In places it closely resembles Millstone Grit.

The Yard Mine Coal occurs a short distance above it in these localities, and in this position may be well seen at the foot of Tunshill and Helpet Edge. It ranges from 2 to 3 feet in thickness, but is an impure coal with many shaly partings and has not been extensively worked.

A continuous section between this coal and the Forty Yards Mine Coal is well exposed along the eastern slopes of Tunshill and Helpet Edge and in the intervening country where the several coals have been worked by means of adits.

The Mountain Mine or Ganister Coal is the most valuable in this district of all the coals below the Arley or Royley Mine, and has been everywhere worked extensively. It ranges in thickness from 18 inches to 30 inches, and is underlain by a valuable bed of fireclay, which in many places contains hard siliceous stone, locally termed ganister. It is the only coal now worked on an extensive scale, and is mined at a considerable depth to the immediate east of Rochdale. The Lower Foot Coal, about 30 feet below it, separated by black shale, is not present everywhere in the district. It has been mined on a small scale at Ogden. The Mountain Mine or Ganister Coal is usually overlain by 36 feet of black shales, above which comes the Bullion or Upper Foot Coal, remarkable for its roof, which is always extremely prolific in shell remains. The roof consists of black shale containing large calcareous nodules known as 'bullions' in which well-preserved *Goniatites* are plentiful. Though seldom exceeding 1 ft. in thickness, this coal, with its distinctive roof, has been found to be remarkably constant over the whole area.

Above the Bullion Coal and the shales which overlie it, in the southern part of the district, is a hard flaggy massive sandstone which forms the prominent scarp of Helpet Edge, and is also well-exposed in Tunshill. Owing to its strong development in the former locality Professor Hull[1] has termed it the Helpet Edge Rock.

To the north of Littleborough, however, the Inch Mine Coal occurs at about this horizon, and overlies a valuable seam of fireclay, 9 ft. thick, which is being mined at the Starring Mine, 1½ miles west of Littleborough Church.

The Forty Yards or Upper Mountain Mine Coal is the highest coal of any importance in the Lower Coal Measures. It is represented throughout the district, and though seldom exceeding 1 ft. in thickness has been worked in several localities. It is at present being mined on a small scale at Ogden. Massive flagstones and shaly mudstones intervene between the Forty Yards Coal and the top of the Lower Coal Measures. The former are being quarried for building and paving stones to the east of New

[1] E. Hull, 'The Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864. p. 16.

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Hey, while the shaly mudstones are being extensively worked for bricks close by New Hey Railway Station.

The Middle Coal Measures form a small inlier to the immediate east of Rochdale. The Arley (or Royley Mine) Coal, which is about 4 ft. thick, has been worked at Belfield Colliery, but owing to the ground being much cut up by faulting, and the great variability in the coal, due to impersistent shale partings, these workings have now been abandoned.

The Glacial deposits cover a considerable portion of the lower ground but are absent from the higher ground at Shore Moor, Walsden Moor, Blackstone Edge, Bleaked Gate Moor, and also on the moorlands east of these localities. That these areas have never been glaciated is confirmed by the fact that wherever a section is exposed under the peat on these moorlands, the surface of the grits is found to be covered with a thick deposit of undisturbed kaolinised 'head' which is absent or has been considerably modified in the glaciated districts.

Mr. Lloyd was engaged on the Yorkshire border north of Todmorden. This area comprises the upper part of the old Yoredale Series and the lower members of the Millstone Grit. The ground is entirely free from drift, except for a few thin patches of gravel and blue clay and scattered erratics reported to have been seen in excavations below the alluvium of the Calder between Todmorden and Hebden Bridge. The tops of the moors have a covering of peat varying in thickness from 4 to 10 feet, in all cases overlying 'head,' which on the lower slopes of the moors and in the upper part of one valley attains a remarkable thickness.

No persistent coal has been found associated with the Kinderscout Grit in this area, but there is evidence in a few places on the moorlands around Walsham Dean and Widdop, of an impersistent thin coal near the top of the Grit. This is probably represented by the four-inch coal recorded in the dam sections of Walsham Dean reservoir, where it is associated with a lenticular bed of shale near the top of the Kinderscout Grit.

An unusual feature in the Kinderscout Grit is the presence, at its base, in Eaves Wood and near Hardcastle Crags, of variously textured beds of highly calcareous grit.

The Third Grit beds for the most part form the high ground frequently as cappings to the moors; no trace of coal has been found in them in this area, though a fairly persistent seam is present in the lowest of the Third Grit sandstones east of Hebden Bridge.

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4. Cumberland District

Headquarters : Whitehaven.

Bernard Smith, M.A., District Geologist.
E. E. L. Dixon, A.R.C.Sc., B.Sc.
T. Eastwood, A.R.C.Sc.
James Maden, M.Sc.
F. M. Trotter, B.Sc.
} Geologists.

Carlisle and Silloth District

The re-mapping of the Old Series Sheet 107 S.E. (New Series 17) has been undertaken by Messrs. Maden and Trotter and more than half completed. The greater part of this area is covered by glacial and recent deposits, the exposures of solid rocks being confined to stream sections along the river valleys upon the eastern border.

NEW RED SERIES

Owing to the exceptionally dry summer Mr. Trotter was enabled to examine more exposures of solid rock than are usually visible along the watercourses. The rocks comprise, in ascending order, St. Bees Sandstone, Kirklinton Sandstone and Stanwix Shales and Marls, and are usually referred to the Triassic Series, the lower sub-division being regarded as Bunter and the upper ones as Keuper. Into the merits of the correlation it is impossible to enter at this stage, and it must suffice to say that the 'gypseous shales' of the Abbey Town boring[1] are thought to represent the Stanwix Shales, as shown on the old Geological Survey map.

The St. Bees Sandstone proved to be a compact, angular-grained, frequently micaceous sandstone, with a minor development of thin chocolate-coloured micaceous shales. The sandstone is even-bedded on the whole, although subdued false-bedding is not infrequent. Thicker posts are quarried for building-stone, thinner ones for flags. In colour it is usually brick-red, but the colour may alter rapidly within short distances from brick-red to white.

The Kirklinton Sandstone[2] is most consistently of a bright red to scarlet colour, but, like the St. Bees Sandstone, it alters rapidly within short distances to buff-red and white. It is a soft, highly false-bedded sandstone, calcareous in places. As a rule it is close-grained but often contains layers of large millet-seed quartz grains. Except at its base and at the top, where it conformably passes into Stanwix Shales, it is devoid of shale bands. It is exposed at several points in the district and underlies Carlisle

[1] 'Geology of the Country around Carlisle' (*Mem. Geol. Surv.*), 1899, Appendix I., p. 52.

[2] For differences between St. Bees and Kirklinton Sandstone *see* Prof. J. W. Gregory 'The Red Rocks of a Deep Bore at the North End of the Isle of Man,' *Trans. Inst. Min. Eng.*, vol. lix., 1920, pt. 2, p. 160.

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as a white or grey sandstone of considerable thickness (*see also* p. 63).

Mr. Trotter has examined two critical sections, showing the junction of the St. Bees Sandstone with the overlying Kirklinton Sandstone: (i) along the River Line eastward from Cliff Bridge (Old Series 106 S.W.—a mile and a half N.E. of Westlinton) Kirklinton Sandstone is seen until Broomhill Farm is reached, when, for a distance of a quarter of a mile, beds of Kirklinton Sandstone type alternate with beds of St. Bees Sandstone and Shale type. Farther eastward nothing but St. Bees Sandstone is visible. The thickness of these passage beds is 250 feet. (ii) In Carwinley Burn, 200 yds. N.E. of the road from Carwinley Mill to Low Moat (Old Series 107 N.E.), and 40 to 50 yds. S.W. of a small bridge, another junction of the two types is seen. Here the change is much sharper, only 25 ft. of passage beds being present. North-west of this critical section the river cliffs are of St. Bees type, and south-west of Kirklinton type.

A curious section of Kirklinton Sandstone in Skew Bank, north of Grinsdale, shows alternations of well-bedded to highly false-bedded greyish-white sandstone with traces of red and buff bands, and some black beds of calcareous sandstone of rather coarser grain. These black-stained layers occur elsewhere and may on analysis prove to be due to the presence of manganese. Irregular patches of grains cemented by calcite stand out on weathered faces and give a false appearance of brecciation.

The Stanwix Shales and Marls apparently succeed the Kirklinton Sandstone with conformity. In an old river-bluff 200 yds. south-west of Cliff Bridge, a 4-inch bed, consisting of thin alternations of Kirklinton Sandstone and Marl, occurs between typical Stanwix Marls above and Kirklinton Sandstone below. Again, although no such passage bed is visible at the junction exposed 100 yds. east of Westlinton Bridge, there is no sign of unconformity.

Stanwix Shales are red and green in colour and consist of two types—arenaceous and argillaceous. Both are calcareous, but in varying degree. Near the base the sandy type predominates, and beds of red, micaceous and slightly calcareous sandstone are not uncommon. Thin beds of impure limestone appear in the more argillaceous parts at a higher level.

A point worthy of note is the tendency of the marls to develop 'skerries.' Three or four feet of sandy marls are overlain by about one foot of rapid alternations of red and tea-green shales, this sequence being repeated several times. This development, however, cannot be said to be characteristic of the marls

Most of the sections in this series occur in the bank of the Eden, notably between Etterby Scaur and Rockcliffe. Between these points the marls form two synclines, the adjacent limbs of which, with the aid of a small fault, bring in the Kirklinton Sandstone at Skew Bank and Grinsdale.

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In the western part of the area, mapped by Mr. Maden, no fresh information has come to light as regards the New Red rocks. Knowledge of the rocks is dependent on two small borings —the one west of Bowness[1] and the other at Kelsick Moss near Abbey Town.[2] Discussion of these bores is left until further field work is done. It is assumed, however, in the absence of any proof of the presence of Rhætic Beds, and after weighing up the available evidence, that the highest New Red beds in the district are the Stanwix Shales and Marls.

LOWER LIAS

The western part of the Liassic outlier west of Carlisle, almost entirely concealed by drift, was mapped by Mr. Maden, who was enabled, by the presence of a more or less persistent feature forming the outer slopes of the drift-covered Liassic plateau, to draw a provisional boundary between Lias and New Red rocks. A small exposure of the Lias occurring in the bed of a stream about 700 yds. north of Thornby consists of fine-textured bluish-grey soapy shale dipping northward at a low angle. It yielded characteristic Liassic lamellibranchs.

GLACIAL

In the district north and north-west of a line drawn from about Rockcliffe to Westlinton, Mr. Trotter finds that the Glacial deposits consist of a series of sands and gravels resting upon an upper boulder-clay separated by a second or 'middle' series of sands and gravels from an underlying boulder-clay.

Both boulder clays are of the red sandy type prevalent whenever ice has passed over Triassic sandstone for some distance. They both contain the same suite of boulders, viz. grey and green Silurian grits (abundant), Criffel and Dalbeattie granites (common), Penrith Sandstone, St. Bees Sandstone, grey and reddish Carboniferous sandstone, a conglomerate (typical of Lower Silurian of Kirkcudbright), local rocks (frequent), and Carboniferous limestone (rare). The maximum thickness of the upper clay is 20 feet.

Where boulder-clay overlies the Stanwix Marls it is much stiffer and more plastic than elsewhere. All the brickfields situated north of Carlisle occur in clay overlying Stanwix Marls.

The middle sand and gravel series consists of gravel, coarse sand, fine false-bedded sand and thin impersistent beds of laminated loam and clay. Where not overlain by the upper boulder-clay they give rise to a featureless plain. The fact that the junction between the lower boulder-clay and the sand and gravel is uneven and pockety, the pockets containing gravel, taken together with the fact that their altitude increases to the north-west, seems to point to their being either (1) part of an outwash-fan thrown out by an ice-sheet lying to the north-west, the laminated

[1] 'Geology of the Country around Carlisle,' *op. cit.*, p. 30.
[2] *Ibid.*, p. 53.

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clay being deposited in shallow pools, or (2) part of a glacial lake deposit. Sand and gravel were first deposited on a land surface. As the water accumulated a shallow lake was formed in which the finer sand and laminated clay were deposited. It is hoped that during the coming field-season further evidence will be obtained which will elucidate this problem.

The upper boulder-clay in its advance has in places contorted and incorporated the beds of sand and gravel. Evidence of the presence of a middle series of sands and gravels, with laminated clays, has been obtained at Carlisle and in the banks of the Eden at Grinsdale; the magnitude of the second advance of the ice-sheet cannot be ascertained definitely until further mapping has been carried out. At Botcherby, Carlisle, the dark red laminated clays, overlain by bedded sand and gravel, are exposed to a thickness of at least 8 feet. Their upper surface is pockety. The clays apparently mark the site of a glacial lake.

Long, snake-like, steep-sided, conical ridges, composed of pure red sand with gravel, the bedding-planes of which are approximately parallel to the slopes of the ridges, rest upon the top boulder-clay and mark the final retreat of the ice from the district. Up to the present only one of these eskers has been mapped in the Carlisle Sheet, but several appear west of it over the Scottish border. The direction of the ridges is a few degrees south of east.

In those districts where the middle sand and gravel is absent the boulder-clay occurs in mounds and ridges, the general direction of their long axes being east and west. Northwards a pronounced drumlin-like topography gives place to one characterised by long steep-sided ridges up to 80 feet in height, and in many cases a mile in length. Taking into consideration the suite of boulders recognised and the trend of the drumlins, ridges and eskers, there can be no doubt that the ice that covered the district emanated from the mountainous country around Criffel.

Farther west, in the Kirkbride district, Mr. Maden reports that drift completely masks the solid rocks. It is in the main a red, or reddish-brown, boulder-clay, generally of a sandy character, although in places it is stiff and clayey. The erratics all appear to be of Scottish origin from the Criffel-Galloway area, and are chiefly grey, green and purple grits and grey and pink granites, and two types of conglomerate, one typical of the Lower Silurian, and the other of the Calciferous Sandstone series of Kirkcudbrightshire. No Lake District types have been noticed. In the Bowness area the clay is not very stony, whilst on the shore, underlying Herdhill Scar (at the railway viaduct) it is a strong red stoneless clay.

As in the Carlisle district, the boulder-clay takes on one of two forms—the drumlin, or the elongated ridge. Examples of the former are to be seen at Cardurnock, Rogersceugh, Drumburgh, Lawrenceholme and Wedholmehill, whilst typical ridges are displayed at Anthorn, Little Bampton and Aikton.

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The major axes of the ridges and drumlins exhibit marked parallelism. In the Cardurnock peninsula the direction is S.W. to N.E. Near Fingland, Little Bampton and Aikton it is W. to E. Near Parton (about 2 miles N.E. of Wigton) it is approximately W.N.W. and E.S.E. These changes in direction indicate differences in the movement of the ice. The boulder-clay is thinner on the western margin of the Liassic outlier, and the solid rock begins to appear in stream sections farther east.

In many places the boulder-clay has included patches of gravel with indefinite boundaries and featureless contours. These are considered to be remnants of englacial and sub-glacial gravels incorporated in the till during movement. At Fingland and Aikhead Lowhouse (about 1 mile N. of Wigton), however, small mounds of gravel can be mapped separately.

POST-GLACIAL AND RECENT

Marine Alluvium.—After the close of the glacial period the land bordering the Solway stood lower with respect to sea-level than at the present day. The Solway must have been much wider, for the waters encroached upon many miles of the land surface and the tide entered the river valleys far above its present limits. The first marine deposits laid down have since been elevated to an average height of 30 ft. above sea-level, but this took place at several periods and has given rise to a series of terraces as follows :—

	Height above O.D. Ft.
River Wampool and Cardurnock Peninsula—	
Raised Beach	33–36
3rd Terrace	28–30
2nd Terrace	19–21
1st Terrace	16–17
Rivers Eden and Esk :—	
3rd Terrace A.	26–30
3rd Terrace B.	22–26
2nd Terrace	19–22
1st Terrace	16–19

In the Cardurnock Peninsula and the drainage area of the Wampool Mr. Maden finds that the alluvium consists of warps resting upon boulder-clay and giving rise at each stage to a perfectly flat countryside. The 1st, or newest terrace, is composed of a dark brown mud or sandy mud with many fine fibrous roots, whilst the older warps are greenish clays or clayey loams with brown mottling around the rootlets, some of which are still visible; this mottling may be seen commencing in the newest warps. This terrace supports a very fine grass, free from weeds, which is in great demand for high-class bowling greens and tennis courts, &c.

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The warps are best studied along the present shore-lines, where in places, such as Drumburgh and Boustead Hill, they are being corraded by the Eden and give rise to a low cliff and a talus of blocks up to 6 by 3 by 3 ft. in size. They are finely laminated and horizontally bedded as seen on weathered surfaces, but on cutting into them freshly the lamination is not visible. On the shore the lamination is clearly brought out, since the fine clayey layers are more resistant to denudation than the sandy ones. In inland sections the warp generally appears as a dark grey, or blue-grey sandy clay. If no mottling appears in the latter it can be taken as indicating the proximity of the boulder-clay, and generally is in the 3rd terrace.

In places the warp is quite a strong bluish stony clay and these patches are considered analogous to the 'scars' which are at present in process of formation in the Solway, being strong courses washed into the warp from neighbouring islands of boulder-clay.

The 3rd terrace is contemporaneous with a well-marked raised beach (*see below*) with which it appears to interdigitate. In the vicinity of Scargravel Point the terrace rests upon the beach. Near Solway House (south of Cardurnock) the beach is seen upon the terrace. The 2nd terrace always forms a notch in the raised beach or the 3rd terrace, whilst the 1st terrace invariably notches the 2nd terrace and appears to be quite recent. Mr. Trotter finds that in the north-eastern district the upper terrace is divisible into two steps. The warps here consist of laminated, grey, argillaceous to sandy alluvium with varying amounts of carbonaceous material, and the three terraces can be traced up the rivers Sark, Esk and Eden. The older terraces stretch farthest up the river valleys.

From a casual survey one would conclude that they were all river terraces, but systematic mapping shows that the alluvium of the rivers overlies the warps; also, in the case of the river Esk, the first river terrace overlies the 3rd terrace of warp.

The separation of these broad spreads of warp from the river alluvium, which is of quite a different character, is of some economic value; the 3rd terrace in particular is capable of bearing crops of cereals, roots or tubers, whilst the river alluvium is mostly under pasture.

The raised beach associated with the 3rd terrace has been traced by Mr. Maden from Bowness, where it rests against the truncated edge of a ridge of boulder-clay, continuously round the Cardurnock peninsula to Anthorn, a more extensive spread than was mapped during the old survey. Its altitude is between 33 and 36 ft. above O.D. Its surface is piled up into a series of parallel ridges or 'fulls' of gravel (similar to those at Dungeness) well exhibited between the viaduct at Bowness and Scargravel Point. The direction of the ridges conforms in general with the seaward contour of the peninsula.

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The beach consists of sand and gravel in which the stones are all from the boulder-clay. They have not suffered much from attrition.

In its southern portion the beach is more stony and less sandy than in the north. It was apparently not formed against a shore-line, but as a spit or 'hook,' running seaward on the flank of the current, the warp being laid down in the stiller waters behind.

Blown Sand.—Blown sand is found at Herd Hill, ¾ mile N. of Cardurnock village, and in Long Wood to the immediate S.E. of Cardurnock. A small patch occurs also about 200 yds. N. of Long Wood.

It occurs in rounded ridges as a bright yellowish-brown sand with a few small stones. Current bedding at high angles is seen in sand pits in each locality. The major axes of the ridges are in the same direction as the ridging of the beach upon which they rest; the latter has probably modified the effect of the wind and brought the blown sand into line with it. The sands are no longer moving and are completely grass-grown; they may belong to the raised beach period.

Recent Alluvium.—(1) Marine.—The sandbanks of the Solway and the sand of the estuaries have been mapped as marine alluvium as far as those points where the estuaries assume the characters of rivers at all states of the tide.

Mr. Maden finds that this alluvium consists of a pale yellow sand, chiefly of quartz, with carbonaceous matter, and often littered with drift-wood. In the neighbourhood of Bowness it is in places fine and muddy. It contains numerous 'scars' (shingle and boulders), some of which, like those south of Cardurnock, are situated on boulder-clay. The 'scars' are constantly changing position, as also are the low-water river channels.

(2) River.—Mr. Trotter reports that broad stretches of alluvium occur along the courses of the rivers Esk, Line and Eden, and, to a minor extent, the river Sark.

The alluvium occurs as a series of terraces which are doubtless due to the uplifts that have given rise to the terraced warps of the coast-line (*see above*, p. 48). The oldest terraces are of gravel and are distributed at intervals; a good example occurs at Longtown, rising to 20 ft. above the present alluvium of the river Esk. Part of H.M. Munitions Factory, Gretna, is situated on two more recent terraces of the Esk. The corresponding terraces of the Sark are gravelly, but contain a greater percentage of sand, whilst those of the Eden contain clay or clayey loam as well as sand and gravel. The modern alluvium forms a grey sandy loam.

In the Kirkbride district the alluvium examined by Mr. Maden consists generally of a reddish brown loam, derived from denudation of the boulder-clay.

Peat.—Long after the rest of the country had been brought under cultivation the district near the Scottish border remained

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as the Romans found it, covered by vast forests and swampy marshes, of which the peat-mosses of to-day are the shrunken remnants. Peaty soil found as far as 2 miles from the boundaries of the mosses shows that at no distant date the latter covered a greater area than they do to-day. The mosses occur in enclosed hollows between ridges of boulder-clay or upon flat country, notably the marine warps, which have proved difficult to drain. About 13 sq. miles of peat have been mapped, chiefly in the Cardurnock, Bowness, Glasson, Solway, Rockcliffe and Drumburgh Mosses; and, wherever possible, the boundaries between cut and uncut peat have been drawn.

The peat is used locally for fuel, and is exploited commercially, in the Wedholme and Solway Mosses for peat-moss litter and in the manufacture of molasses meal, oil cake, manure and brown paper. The method of cutting in the latter case is on the Dutch system.

Whitehaven District

The remapping of the Whitehaven Sheet (Old Series 101 S.W., New Series 28) was commenced by Messrs. Smith, Dixon and Eastwood, and considerable progress made during the year. Mr. Maden also took a share in the work. The complexity of the geological structure, however, renders it necessary to postpone judgment upon many points until more evidence has been collected.

The solid rocks consist of a series of New Red rocks lying unconformably upon the Carboniferous—comprising Coal Measures, Millstone Grit and Carboniferous Limestone Series—which in their turn are unconformable upon the Skiddaw Slates.

SKIDDAW SLATES

The rocks that form the western margin of the fells between Ennerdale and Loweswater are shown as Skiddaw Slates on the Old Series Geological Survey maps, and, in default of proof of definite age, this name may be retained. Mr. Dixon, who examined this tract of country, finds that the rocks vary in composition from clay-slates to fine-grained sandstones and striped quartzites, with rare and thin bands of fine conglomerate, the whole coloured grey; parts weather white. No fossils have been found, despite wide exposures of bedding-planes in slates little affected by cleavage or heat. Nor has it been possible to determine a sequence; hence both true age and structure remain unknown. Over most of the area the beds show a north-westerly dip of from 30° to 60°, which is probably illusory, for in a few clear sections it is seen to be the inclination of the limbs of isoclinal folds.

Hornfels and spotted slate, results of the intrusion of the Ennerdale Granophyre,[1] are more widely developed than is shown on the former map. Their distribution is irregular,

[1] The petrological characters of this rock have been described by Dr. R. H. Rastall, *Quart. Journ. Geol. Soc.*, vol. lxii, 1906, p. 253.

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possibly on account of underground extension of the granophyre. No other intrusive rocks have been found by Mr. Dixon in this area.

The mapping of the faults in the slates is important, because some have locally become workable lodes of hæmatite and some are in line with known cross-faults in the Carboniferous Limestone. A sheaf of N.W. to S.E. faults has been described by Mr. Smith in the memoir on the hæmatites of the district,[1] as it has yielded ore at Knockmurton and Kelton Fell. Old workings and trials enable some members to be traced N.W. almost to the Glacial drift of the coastal plain and S.E. to Crossdale Beck, but there is little doubt that the sheaf, though probably carrying no ore, continues in the latter direction along the S.W. faces of Banna Fell and Herdus.

A parallel fault appears to run from the south end of Hen Comb to the Cogra Reservoir, and another is suggested N.E. of Blake and Owsen Fells, in line with the great south-westerly downthrow shown on the old map as dislocating the limestone-outcrop of Scalesmoor and Dean. Neither fault is exposed or known to be mineralised.

On the south side of Ennerdale Water Mr. Maden found that the Skiddaw Slates fell within the metamorphic aureole of the granophyre, and consisted chiefly of grey-green to pink striped hornfels, traversed by a few veins of hæmatite (formerly worked for ore) and at least one dyke.

Farther south near Water Mill to the south-east of Cleator Moor Mr. Smith discovered a suite of dykes, apparently of acid type and vesicular, trending from north-east to south-west in uncleaved but highly folded Skiddaw Slates. These are not shown upon the Old Series map.

CARBONIFEROUS LIMESTONE SERIES

The outcrop from Yeathouse to Pardshaw has been examined by Mr. Dixon, who also made use of many records and the cores of borings in the Lamplugh district.

It is obvious that along this outcrop, where valuable deposits of hæmatite are being worked and exploration is being actively pushed northward, a knowledge of sequence and structure is vital to the mining industry and that conclusions under either head must be preceded by patient accumulation of evidence.

The seven limestone bands recognised by Mr. J. D. Kendall persist throughout; the 3rd and 4th beds, which in places elsewhere are grouped together as the 3rd (making a total of six) are distinct. The detailed lithological and faunal characters of the whole series have been described recently by Mr. C. Edmonds,[2] of Moor Row, who by their means has been able to compare

[1] 'Special Reports on the Mineral Resources of Great Britain,' vol viii. (*Mem. Geol. Surv.*), 1919, pp. 164–7, fig. 29.

[2] 'The Carboniferous Limestone Series of West Cumberland,' *Geol. Mag*, 1922, pp. 74–83, 117–31.

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the sequence with that at Alston Moor and with the zones based by Vaughan and Garwood on the developments in the S.W. and N.W. provinces. The Survey is greatly indebted to him for freely communicating his results before publication and for pointing out, on the ground, the features of the different bands. His criteria have been tested, and although, as might be expected, all of them do not appear in every boring, by their means it is now possible (unless the original characters of the limestones have been destroyed by hæmatitisation or dolomitisation) to recognise the horizons of even fairly short lengths of core. At some levels, indeed, single beds are sufficiently distinctive to be identified. For details reference should be made to his paper. The following are points of some general interest.

The Bottom, or 7th Limestone, is remarkably persistent, despite the strong unconformity at its base with the 'Skiddaw Slates.' Its horizon is the *Nematophyllum minus* subzone, or S_2, which is the level also of the base of the Carboniferous Limestone around the northern end of the Lake District.[1]

This persistence testifies to the remarkably even character of the platform of older rocks on which the limestones have been laid down. The horizon was evidently one of widespread, though shallow, marine transgression; it forms the base of the Carboniferous Limestone most frequently also along the North Crop in South Wales.

The Clints, or 4th Limestone (D_1 and D_2 parts), includes a number of levels at which the upper surface of a bed of limestone, underlying a clay-mudstone ('mottled shale'), or sandstone, is penetrated by 'pipes' or 'pot-holes' up to several feet in diameter and several yards in depth. The pipes are filled with mudstone or sandstone like the overlying bed and recall those observed by Greenly in the D_2 and D_3 limestones of Anglesey.[2] The piping, it is agreed, has been contemporaneous. Prof. W. H. Hobbs suggests (p. 615) that the Anglesey pipes are similar 'to the sand funnels produced by the derangement of ground water by earthquakes,' whereas Mr. Edmonds concludes that the Cumbrian pipes are due to repeated incidents of emersion and subaerial erosion. Channelling, observed by the latter in one of the limestones, might be caused by earthquake-waves, as Greenly remarks of some planes of erosion in Anglesey. But the fact that all the known pot-holes in Cumberland are filled with continental or lagoon deposits points directly to elevation. They may be parallelled with the piping and subaerial erosion of limestones at the junction of the Lower and Upper Avonian at West Williamston, Pem.,[3] and Pendine, Carm.,[4] and at that

[1] K. W. Earle, *Abstr. Proc. Geol. Soc.*, No. 1076, 1921, p. 10

[2] 'The Geology of Anglesey' (*Mem. Geol. Surv.*), vol. ii., 1919, pp. 613–6, pls. XXXVIII. and XXXIX., figs. 289 and 290.

[3] 'The Country around Haverfordwest' (*Mem. Geol. Surv.*), 1914, pp. 141–2, pls. I and II.

[4] 'The Country around Carmarthen' (*Mem. Geol Surv.*), 1909, pp. 81–2.

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of the Upper Avonian and Millstone Grit at Haverfordwest[1] and Ifton, Mon.,[2] both of which junctions are unconformities.

The Top, or 1st Limestone, Mr. Edmonds shows, is possibly D_3, and corresponds to the Main Limestone of the Yoredale Beds. The shales and sandstones interbedded with the limestones yield a few plants, and it is hoped that, by means of these and the flora and fauna of the Millstone Grit above, it may be possible to help towards a comparison of the classifications—based on different groups of organisms by Vaughan, Garwood, Kidston and Wheelton Hind—of the various deposits that intervene between the Carboniferous Limestone and the Coal Measures.

The distribution of hæmatite has long been known to depend partly upon fault-planes and similar fissures, partly upon the presence of impermeable shales. No evidence was obtained last year that it had been materially affected by the kind of limestone subject to replacement. It is certain that in ore-bodies many different kinds of limestone, such as pseudobreccias, coral and crinoid bands, have been altered. A parallel may, perhaps, be drawn with 'subsequent' dolomitisation which has frequently accompanied hæmatitisation. Such dolomitisation acts selectively on different constituents of a limestone only where it is incomplete.

A small tract of Carboniferous Limestone surveyed by Mr. Eastwood forms an outlier at Hensingham, but the upper part only of the formation is exposed, the lower portion being cut out by a fault bringing in St. Bees Sandstone on the east. A fault on the north, by Overend, throws Millstone Grit against the Limestone; while on the south-east, at Netherend, the inlier is terminated by the Ingwell fault which introduces Trias. Exposures depend upon quarrying and boring operations. The quarries are disused, but the largest furnishes a good section in the 1st Limestone succeeded on the west by Millstone Grit. A small quarry, lying farther east, shows the parting (shales and sandstones with a thin coal) between the 1st and 2nd Limestones, and also a few feet of the top of the latter. The 3rd Limestone is exposed indifferently farther south-east.

The inlier has been extensively prospected for hæmatite but the bores have failed to reveal payable ore. Borings of recent date have proved the full thickness of the Limestone Series to be 700 ft. between the Millstone Grit and the Skiddaw Slate.

Exposures of Carboniferous Limestone are scarce in the area mapped by Mr. Smith between Moor Row and Bigrigg.

The 1st Limestone, with west-south-westerly dip, is exposed in some old crop-workings a few yards N.E. of the disused Gutterby Pit. The Bigrigg-Ingwell Fault brings it to outcrop again farther west, south of the Pallaflat Railway line, where it appears, dipping in the same direction and capped by Millstone Grit, in a range of old quarries.

[1] 'The Country around Haverfordwest' (*Mem. Geol. Surv.*), 1914, p. 151.

[2] *Geol. Mag.*, 1921, p. 157, pl. II.

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Borings at Bigrigg prove that the total thickness of the Carboniferous Limestone in this district is from 750 to 760 ft.; and it may be pointed out that the individual limestones from the 1st to the 6th, or 1st to the 7th, according to the grouping, have similar characteristics to those in the Yeathouse-Pardshaw area.

The limestone is extensively mineralised, some of the chief West Cumberland haematite mines occurring in this neighbourhood.

MILLSTONE GRIT

The strata, from a hundred to two hundred feet in thickness, lying between the Udale Coal and the top of the 1st Limestone are taken provisionally as the Millstone Grit Series. In the Hensingham area Mr. Eastwood finds that typical grit, as known in Lancashire and Yorkshire, is not well developed, the strata consisting mainly of sandstone and dark shales with some thin lenticular bands of limestone. The lower part of the formation, showing rough sandstone, is exposed around Overend; that capping the above-mentioned large limestone quarry yields numerous casts of plants of which the commonest is *Lepidodendron*. The upper part of the series is best seen in Snebro Gill, Hensingham, though sections occur in the gills southwards to Chapel House. Snebro Gill is, for the most part, floored by a dark earthy limestone. This is succeeded by dark shales with lenticular bands of limestone varying from dark earthy types, occasionally crowded with brachiopods, to a pale shaly type made up almost entirely of encrinite stems. The shales contain occasional sandstones.

In the area farther south, mapped by Mr. Smith, a bore-hole south of the mineral railway-cutting (Pallaflat Railway) at Bigrigg proved approximately 150 ft. of the Millstone Grit Series, with a group of sandstones both at the top and bottom, and shales with occasional sandstones and ironstones between. Black goniatite shales occur about half-way down this series and are exposed[1] in the cutting a few yards S.W. of the bridge over the railway. Goniatites occur at other horizons, in ferriferous nodules in red and purple shales, but the fossiliferous horizons are by no means constant. The lowest bed is a mottled sandy shale 2 ft. thick, but this is absent in places. The palæontological evidence has yet to be worked out.

An old quarry, situated 130 yds. E.S.E. of the bridge, shows 6 ft. of grit on thin shales, on 12 ft. of the 1st Limestone.

Farther west the Breccia, as proved by boring, overlies a thickness of 424 ft. 6 in. of purple shales, red, grey or mottled micaceous shales and laminated sandstones, with occasional beds of coarse red and grey felspathic grit and white fine-grained sandstone. Black shales occur at intervals towards the base and are in some cases fossiliferous. The lowest bed here, overlying

[1] Our attention was drawn to this locality by Mr. C. Edmonds.

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the 1st Limestone, consists of 3 ft. of dark fossiliferous shale and mudstone, beneath a medium-grained felspathic grit.

The lower 180 ft. at least of this series, below the top of a bed of coarse felspathic grit, must be regarded as Millstone Grit; most of the beds above, chiefly micaceous shales and shaly sandstones, may represent the lower part of the Coal Measures stained by iron-bearing waters from the New Red Rocks.

COAL MEASURES

The Whitehaven coalfield is much broken by faults of considerable throw, though in places of small lateral extent. On the whole, at Whitehaven, the measures incline westwards, while south of Saltom their dip swings round to the south-west and soon brings on a thick cover of post-Carboniferous rocks. North of Whitehaven the measures frequently dip inland, and only take on a pronounced westerly dip when the coast is reached. This dip is greater than the slope of the sea-bottom, and thus enables coals to be wrought with comparative safety beneath the sea-bed. The workings of the Whitehaven Collieries extend seawards for a distance of over four miles from the coast.

The Coal Measures of the southern part of the coalfield, examined chiefly by Mr. Eastwood, fall naturally into two subdivisions, the lower containing the chief seams of coal, and the upper little or no coal. The former consists of grey types of sediments common to the Lower and Middle Coal Measures of the neighbouring coalfields, but at this stage all the coal-bearing strata will be described as the Productive Measures. In the latter or upper sub-division, the prevalent tint is purplish, shading to red, grey and brown. Sandstones usually predominate, though the upper part contains much shale and occasional bands of limestone with *Spirorbis*, thus linking the sub-division with the barren Upper Coal Measures of the Midlands. This group will be described as the Whitehaven Sandstone, and its relation to the Productive Measures will be considered at a later stage.

Productive Measures.—In the Whitehaven area Productive Measures attain a thickness of upwards of 1,200 ft., taking the base at the Udale Coal, the relative position of which, together with that of the prihcipal seams, is indicated in the generalised section, Fig. 1. The measures consist of the usual assemblage of shales, clays and sandstones with occasional ironstones, and numerous seams of coal. They do not differ materially from top to bottom, and are remarkably impersistent. Sandstones frequently pass, both laterally and vertically, into sandy mudstones, shales and fireclay. In general the sandstones are coarsest in the lower part of the group. That immediately above the Four Foot Coal often occurs as a rough grit with quartz fragmehts up to half-an-inch in diameter; that above the Six-quarters Coal as a coarse sugary sandstone; while those at higher horizons—above the Main Band, above the Bannock Band, and above the

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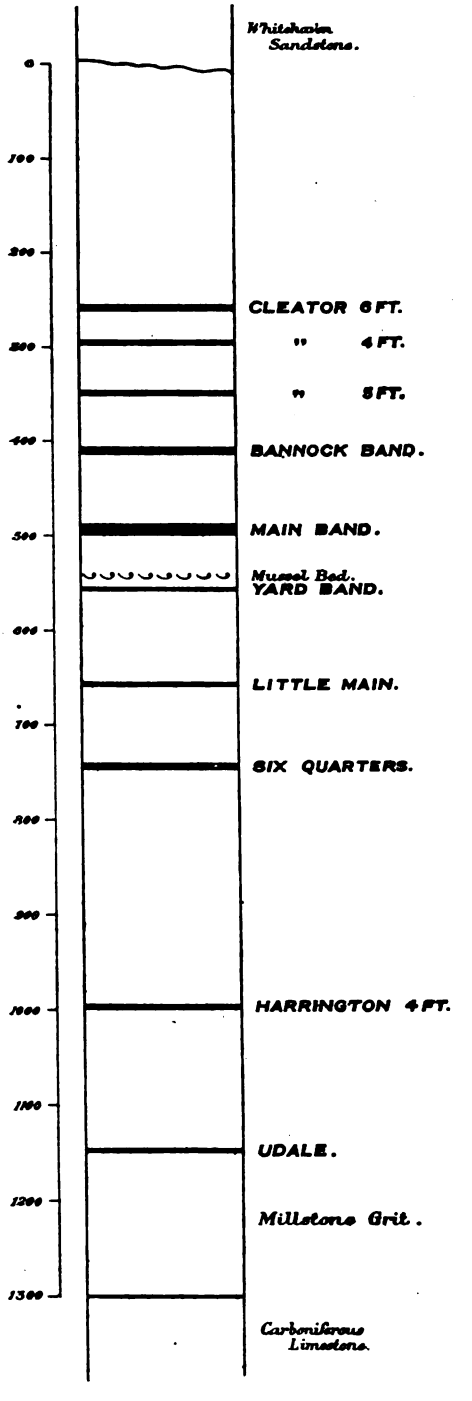

FIG. 1.—*Generalised Section showing the sequence of the chief Coal-seams in the Whitehaven District.* (Depths are given in feet.)

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Cleator Six Foot or its representative—though often coarse, are usually of medium grain. The sandstones vary in colour from white to grey, and weather buff or yellow. The argillaceous beds are as inconstant as the sandstones—black shales in one part of a quarry passing into light clays in another. As a rule, those below the Main Band are of a darker shade of grey than those immediately above that coal, while those above the Bannock Band are frequently pale greenish and bluish grey. Apart from these characters the only approximate index of horizon so far discovered is the Mussel Bed a few feet above the Yard Band. This consists, when well developed, of a dark ironstone, about one foot in thickness, closely packed with large *Carbonicola*, but is frequently accompanied, or replaced, either wholly or in part, by dark shales containing either scattered *Carbonicola* or heart-shaped fish-scales. In boring for coal this bed escapes notice unless special watch is kept. Dark shales with *Carbonicola* occur at other horizons, notably some distance above the Four Foot Coal in Andrews Gill north of Micklam, and about the horizon of the Two Foot Coal around Distington. It will be seen, therefore, that unless a considerable section is exposed or the coals are well developed, it is almost impossible to allocate correctly the position in the sequence.

The coals belong to the bituminous class suitable for household use, general steam raising, and also to some extent for coking. Individual seams vary in thickness and may be split by partings. All are subject to 'nips' and occasionally are entirely wanting over hundreds of acres. In general the lower coals thin away southwards while the upper seams deteriorate in a northerly direction.

The *Udale Coal*, averaging about 3 ft. in thickness in the Harrington area where it was at one time worked, is thin and worthless around Whitehaven. It has been located in Walkmill Pit, and at the surface in Bedlam Gill, Hensingham, where the dark shales above it yield goniatites.

The *Four Foot Coal*, wrought in the past at Harrington Collieries, is almost valueless at Whitehaven, being either a thin band or split by shales.

Thin chance seams occur between the Four Foot and the Six-quarter seams and may be seen associated with dark platy shales at the foot of Middle Gill, in Andrews Gill and around Common End, Distington.

The *Six-quarters*, also known as the *Yard Seam*, is the most wrought of the seams below the Main Band. It averages about 3 ft. of workable coal, with a few inches of 'rattler' or bastard cannel at its top. This seam with its rough sandstone cover crops out below Moresby House, under Middle Gill Farm, Barngill Quarry, the gill by Harrington Mill and at Common End, Distington.

North of Low Scalegill, between the railway and High Low Hall, Mr. Smith notes that the Low Main or Six-quarters Coal

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dips south-eastward along a line of fault at angles varying from 25° to 65° towards the workings from several old pits. The coal occurs as lenticles nipped-out along the fault-plane. A band of cannel occurs in grey shales at a little distance below the coal.

Though thin seams occur above the Six-quarters Rock, the only one of importance is the *Little Main* or *Two Foot Band*. As the latter name implies, it is only about 2 ft. in thickness, but is frequently worked as it is of good quality. The roof is of shale with a few inches of 'rattler' at the top of the coal, while the floor is generally a good fireclay.

The thin seams between the Little Main and the Yard Band are as a rule valueless. The dark shale roof of one cropping out just below the railway embankment in Middle Gill has yielded *Lingula*, but this horizon has not been located elsewhere.

The *Yard Band*, with two or three feet of coal, though sometimes worked, is not a high-grade seam. It crops out at the east side of the railway embankment in Middle Gill, at several places around Distington, also with good Mussel Bed above it in the White Park of Whitehaven Castle, and the banks of the Keekle near Priest Gill; while the Mussel Bed is seen near the fault bringing in the Breccia at Howth Gill, Frizington.

The Yard Band with both Fish and Mussel Beds has been detected by Mr. Smith in Bearmouth Gill and Benhow Wood.

No seams of importance lie between the Yard and Main Bands, though thin beds of coal and cannel occur.

The *Main Band*, averaging five or six feet of coal and sometimes attaining a thickness of ten or twelve feet, is the most valuable seam in the district. Some cannel is frequently present at the bottom of the seam. The roof is variable: it frequently consists of light blue-grey mudstone with posts of sandstone, overlain by a considerable thickness of sandstone. The outcrop of this seam was exploited during the recent mining dispute at Middle Gill, below Castle Rigg, in Stubbs Gill 'lonning' and Boonwood in the neighbourhood of Distington, and below High Wreah in the banks of the Keekle. The sandstone above it—sometimes referred to as the Main Band Rock—is well developed and exposed in the River Keekle above Walk Mill.

Mr. Smith finds that the Main Band, worked so extensively in the old Howgill Collieries, crops out on the west side of the St. Bees-Whitehaven valley beneath Greenbank, and was dug during the recent dispute at Bearmouth Gill near Coalgrove Bank, where it dips west-south-west. In the Bearmouth gully the Yard Band and an underlying coal were also laid bare.

Main Band coal has been worked from Ladysmith Shaft as far south as Hannah Moor and Rottington in the Whitehaven Colliery under St. Bees Headland.

In the valley floor the coal was worked at the old Scalegill Colliery between Stanley Pond and Scalegill Beck.

It was also worked at the Whinhyhill Colliery near Cleator Moor.

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The *Bannock Band*, frequently split by one or more partings, and yielding five or six feet of coal of fair quality, is reported by Mr. Eastwood to have been wrought to a rather less extent than the Main Band at the principal collieries. It crops out with that seam at the foot of the slope along the west side of the St. Bees valley, though the actual basset is masked by boulder-clay. The overlying sandstone, the 'Bannock Band Rock,' is somewhat similar to that above the Main Band except that it is in places of finer grain and of bluish-white tint. This rock appears on the beach north of Lowca Point, and in the disused quarry at Sand Close near Walk Mill.

Mr. Smith examined faulted outcrop workings in the Bannock Band about 100 yds. east of the old Moss Pit, west of Coalgrove Bank. The coal at one point was 8 ft. in thickness, the roof being a black shale with fish scales. The Bannock Band with associated coals was also exposed, dipping south-westward, in surface-workings in Benhow Wood, where it is repeated by a fault aligned almost directly with the fault that throws in the opposite direction, bringing the Coal Measures against the Magnesian Limestone (p. 65) in Bellhouse Gill.

Mr. Eastwood reports that the seams above the Bannock Band are of less value than those below, and are frequently split by partings of shale and clay. They and the measures between them are even more variable and less easily recognisable than the seams below. The best section in this belt of strata is exposed in the quarry of the Whitehaven Brick Co., about one mile south of Whitehaven, though smaller exposures may be noted in the cliffs and on the beach both north and south of the harbour. Though the seams were wrought in the early days of mining, they are not exploited on a large scale as a rule at the present time. The principal seams have been worked in the Cleator and Frizington district under the names given in the section on Fig. 1, p. 57. The lowest, or *Cleator Moor Five Foot*, has been tried at Oatlands Colliery, where it is known as the China Bed, and at the old Greyhound Pit as the Spar Band. This seam crops out on the railway at Lowca Point and in Lowca Beck below Moresby Hall. The next, or *Cleator Moor Four Foot* seam, probably represents that known at Whitehaven as the *Preston Isle Yard Band*. The measures between these seams are usually clays and shales. Sandstones are locally more abundant above the *Cleator Six Foot* horizon, and may be seen capping the cliffs south of Parton.

Whitehaven Sandstone Series.—Mr. Eastwood finds that the Whitehaven Sandstone Series consists of sandstones and shales varying from purple and dull red to pale grey. Sandstones predominate in the lower part of the series, shales being thicker and more abundant at higher horizons which are characterised by the presence of thin bands of Spirorbis limestone. In the area surveyed by Mr. Eastwood the series has been proved to a thickness of 600 feet.

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The sandstones vary from fine flaggy beds to coarse grits with fragments of quartz up to the size of a pea; but usually the rock is a rough fairly coarse sandstone occurring in thick beds separated by thin irregular partings of shale. While no actual grains of felspar have been noted, the rock is characterised by abundant white specks that suggest the former presence of that mineral. As a rule mica is not common. Almost every exposure shows small cakes and blebs of red shale or mudstone incorporated with the sandstones, and sometimes so heavily charged with iron as to be mistaken for pebbles of hæmatite. These blebs vary from isolated patches to aggregates forming lenticular beds recalling the 'pellet rocks' of the Keele Beds of the Midlands, and are evidently of similar origin. Shale partings in one portion of a section may be ascribed to 'pellet rock,' but elsewhere may arise from local contemporaneous erosion.

The shales call for no special remark except for the occurrence in them of limestones. These vary in thickness from about two feet to lines of small nodules, and in character from hard porcellanous creamy limestone to calcareous sandy mudstone. *Spirorbis* has been detected in the former type alone. It is interesting to note that hæmatite replacing a bed of Spirorbis limestone was at one time worked at Millyeat near Frizington.

From the foregoing account it might be assumed that the Whitehaven Sandstone is at all times easily distinguishable from the Productive Measures, but this is not the case. It frequently happens that the normal colourings of the Whitehaven Series and the Productive Measures are reversed, especially where the latter are much broken. The question then arises as to how much, if any, of the red and purple colour of the Whitehaven Series is original and how much is due to staining from the Trias. The widespread nature of the colouring and the occasional repeated alternations of red and grey rocks suggest that much of the colour is original, though the presence of greenish and grey patches in one part of a section, and of very dark red and purple at another, points to some migration of colouring matter.

From the coast at Whitehaven to about two miles inland, the base of the Whitehaven Sandstone keeps approximately 500 feet above the Main Band Coal, and the junction seen on the beach near William Pit appears to be a passage from the Lower (or Productive) series to the Upper. It might be inferred that the Whitehaven Sandstone is conformable to the Productive Measures and that red rocks encountered closer to the Main Band are not Whitehaven Sandstone but stained Productive Measures. This has been disproved by mining operations beneath a large tract of Whitehaven Sandstone, that extends over Weddicar Rigg. The eastern workings from Walk Mill Colliery prove that the Main Band is about 300 feet below the surface. Unless there is a remarkable thinning of the measures between the Main Band and the base of the Whitehaven Sandstone (a point that has not been proved), it follows that the latter is unconformable, and cuts

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down rather rapidly into the Productive Measures, removing the upper coals one by one as it proceeds eastwards.

NEW RED SERIES

In the area west of the St. Bees–Whitehaven valley, viz., St. Bees Headland or Preston Isle, the rocks comprised under the above title consist of the following :—

	Thickness at Barrowmouth.
St. Bees Sandstone	200 ft.
Gypsiferous Shales and Marls ...	100 ,,
Magnesian Limestone	14 ,,
Breccia	6 ,,

UNCONFORMITY

Coal Measures (Whitehaven Sandstone).

This sequence, as exposed on the beach and in the cliffs at Barrowmouth, Saltom Bay, was described long ago by Sedgwick, Binney, Murchison and Harkness, who appear to have assigned the whole group to the Permian Series. On the Old Series Survey map the Magnesian Limestone and Breccia are shown as Permian and the Gypsiferous Shales as Trias.

As the rocks are followed south-eastward, however, into the Bigrigg and Cleator district, Mr. Smith finds that some remarkable changes take place that tend to throw doubts upon the latter correlation. At this stage it seems best to classify all the beds as 'New Red Series' and consider only the facts.

No great change takes place in the thickness or character of the three lower members up to a point near where they are last observed west of the St. Bees-Whitehaven valley, but when they reappear in Linethwaite Beck and Parkhouse Gill on the east side of the valley considerable changes have occurred. (1) The Breccia below the Magnesian Limestone has increased considerably in thickness. (2) The Limestone is reduced to two feet and finally disappears altogether. (3) Breccia of exactly the same type has developed in the overlying shales and marls, which contain layers, pockets and fine dustings of breccia material at still higher levels. (4) Gypsum and anhydrite are usually absent.

In the Egremont district and beyond the southern margin of the Whitehaven Sheet, we find that the lower parts of the St. Bees Sandstone contain layers of breccia material, and the sandstone rests directly upon thick breccias (with included sandy and shaly beds) which must represent the whole of the Gypsiferous Shales, Magnesian Limestone and Breccia of the Barrowmouth section, if not some of the St. Bees Sandstone also.

Not only is there a lateral passage of the lower beds into breccia, but each division, by including some beds of the types above or below, passes by intermediate and sometimes imperceptible stages into the next division. The whole series, in fact, presents a conformable sequence.

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This state of affairs was recognised by R. Russell, who, in writing to Topley[1] in 1888 states that " when we come to consider the stratigraphical condition of these beds, we find that they all pass gradually either horizontally or vertically, or in both directions, from one to the other. No natural division occurs amongst these Red Rocks."

In the southern district again, deep bore holes show a great thickness of almost shale-less sandstone, overlying the sandstones and shales typically developed in St. Bees Headland. These have been claimed by Prof. J. W. Gregory[2] to represent Kirklinton Sandstone. No definite boundary can be drawn, however, between the two divisions, for similar types of sandstone occur both above and within the lower (or St. Bees) shaly division. Thus we are confronted with the same conditions as in the Carlisle district (p. 44), where the St. Bees Sandstone passes into Kirklinton Sandstone. In the district under discussion, however, the difference between the two types is less marked, and they obviously arose from the same physical conditions.

The Breccia.—At Barrowmouth Mr. Smith finds that the Breccia rests upon a fairly even eroded platform of well-jointed Whitehaven Sandstone. Here and there the floor is irregular, and the breccia fills joints and cracks quite 3 ft. below the general surface of the platform : some ledges in the platform are underpacked. The platform, however, is not nearly so irregular as the wave-cut platform that is being formed by present marine action.

The Breccia dips S.W. at 5° and consists chiefly of a dark reddish-purple sandy or muddy deposit full of angular to subangular fragments, amongst which Carboniferous sandstones, liver-coloured quartzites and hæmatitised shales and mudstones are predominant. About 5 to 10 per cent. of the fragments consist of Carboniferous limestone and are in rounder forms and frequently dolomitised. Cherts also are present. The larger fragments of the Breccia are from 6 in. to 9 in. in length. Thin sandy layers and lines of small stones exhibit a well-marked bedding.

At the western end of Benhow Wood, N.E. of Demesne, the Breccia is 9 ft. thick and contains angular fragments of Carboniferous limestone up to one foot in size. In Linethwaite Beck (Parkhouse Gill) the Breccia beneath the Magnesian Limestone is red and of similar type, but has increased to over 30 ft. in thickness.

Breccia occurs also above the Magnesian Limestone, evidently developed in the Gypsiferous Shales and Marls, of which about 40 ft. may be here assigned to breccias. That immediately overlying the Limestone cannot be differentiated from certain beds below. The greater part of the Shale series now ascribed to the Breccia consists of soft red micaceous laminated sandstones,

[1] MSS. in possession of Geological Survey.

[2] 'A Deep Bore at Seascale in Cumberland,' *Geol. Mag.*, 1915, pp. 146-149.

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red shales and mudstones, occasionally nodular, containing here and there chips of marl and fragments of extraneous rocks. Farther to the south-east, near Parkhouse Farm, the lower breccia dipping west at about 15° averages 50 ft. in thickness, whilst the Magnesian Limestone is from 1 foot to 1 foot 6 in. thick, and the upper breccia is similar to the lower and about 100 ft. in thickness. Both the higher and lower breccias contain a large proportion of Carboniferous limestone.

Above the breccias, 80 ft. to 100 ft. of the beds must be ascribed to the Shale and Marl series beneath the main St. Bees Sandstone; they contain nests of fine breccia and bands of ripple-marked sandstone, thus having some of the characteristics of Breccia and some of St. Bees Sandstone. The offices of Parkhouse Mine are situated on the outcrop of the lower breccia, which rests upon the ' Millstone Grit ' exposed farther east in the Bigrigg (Pallaflat) railway-cutting (p. 55).

Instructive sections in the breccias mapped by Mr. Eastwood are found in Dub Beck, between Weddicar Hall and Millyeat, where the formation rests on the upper part of the Whitehaven Sandstone series, the actual junction being seen near the sharp bend of the stream by the weir. Unlike the section at Barrowmouth, this junction forms a regular plane, whether the underlying rock be sandstone or shale. The breccia at the base does not differ materially either in composition or size of fragments from that exposed for twenty feet above it, and consists of the usual assemblage of angular fragments of Skiddaw Slate, igneous rocks probably derived from the Borrowdale Series, and Carboniferous limestone, the last-named forming nearly 20 per cent. of the stones. The breccia contains at this point occasional large fragments of Whitehaven Sandstone. Although the constituents are not regularly arranged the rock occurs in a series of thick even posts.

Near Weddicar Hall the Breccia is cut off by a fault throwing in Coal Measures. It is next seen in the railway-cutting at Keekle Terrace, where it rests on Whitehaven Sandstone lower in the sequence than at Millyeat. Between Keekle Terrace and the Limestone inlier at Overend, the Breccia underlies St. Bees Sandstone, but its one outcrop is in the gully west of Keekle Bridge.

Northwards the Breccia rests on Whitehaven Sandstone in the Keekle at Walk Mill, where it is let in by trough faults against Bannock Band Rock on the north-east, and measures about the Yard Band horizon on the south-west. Near the latter fault the Breccia approaches the St. Bees type of rock. On Weddicar Rigg, eastwards of the Keekle, breccia is worked intermittently for road-gravel. It is much less consolidated than elsewhere; all the fragments are filmed with hæmatite and limestone is conspicuous by its absence.

The Magnesian Limestone.—This formation, as mapped at Barrowmouth by Mr. Smith, consists of a lower 8-ft. magnesian

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limestone occurring in posts up to 1 ft. 9 in. in thickness, succeeded by a 3-ft. belt of shales with thin limestones, which are overlain by 3 ft. or more of thin limestones and shales. These pass upwards into the Gypsiferous Shales and Marls, but the top of the section is obscured by landslides.

The lowest foot of limestone is flaggy and contains fragments of shale, sandstone, &c., like those in the underlying breccia, whilst scattered pellets occur quite 3 ft. above the base. Occasionally the limestone is crystalline; at other spots it is cavernous and rubbly, and contains layers of poorly preserved fossils, including *Pleurophorus costatus* (Brown), a well specialised form characteristic of the higher part of the Magnesian Limestone of Co. Durham, and widely distributed in the Zechstein of Germany and the Permian rocks of Russia.

Inland, an old quarry N.W. of Barrowmouth Farm exposes at one point about 2 ft. of limestone-breccia on 2 ft. of platy magnesian limestone dipping S.W. at 10°. In the centre of this breccia is a band of extraneous pebbles. These beds overlie about 10 ft. of more solid magnesian limestone. Both here and on the coast the limestone has thin layers of secondary gypsum on the joint-faces.

South-eastward Mr. Smith observed that the rock was exposed in road-sections and old quarries, usually dipping S.W. at about 10°. On the west side of the St. Bees road at Roskapark Wood, ¼ mile N.E. of Demesne, about 15 ft. of the limestone is seen; whilst on the east side of the road boulder-clay overlies 12 ft. of limestone on 9 ft. of breccia resting on purple Coal Measures sandstones and shales. Farther south-east the limestone is 16 ft. thick in Bellhouse Gill, where it is faulted against Coal Measures.

Gypsiferous Shales and Marls.—At Barrowmouth the Gypsiferous Shales and Marls aggregate about 100 ft. in thickness and pass upwards into the lower shaly division of the St. Bees Sandstone. The gypsum occurring here[1] was estimated by Binney to be 29 ft. thick, the largest bed measuring 15 ft. It is white and saccharoidal, but is frequently stained pink or mixed with reddish marl. It was mined at intervals between 1863 and 1908.

Beds above the gypsum zone are exposed a few dozen yards S.W. of Barrowmouth Farm and consist of micaceous laminated shales, and blocky sandy marls with fine dustings of extraneous materials, forecasting the oncoming of breccias at this horizon farther inland.

In Roskapark Wood, north of Demesne, the beds dip S.S.W. at from 6° to 8°, and consist of blocky and nodular marls and shales with bands of thin grey magnesian limestone in places. The marls are occasionally spotted green. In Bellhouse Gill,

[1] 'Special Reports on the Mineral Resources of Great Britain, vol. iii., Gypsum and Anhydrite' (*Mem. Geol. Surv.*), ed. 2, 1918, p. 15.

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over 1 mile S.E. of Barrowmouth, the series contains thin beds of red sandstone in thin sandy and blocky micaceous flags and marls with manganese staining. Some bands are greenish. In this area the beds are probably over 100 ft. thick, and give rise to a broad stretch of ground of low relief between Roskapark Wood and Sandwith.

In Parkhouse Gill the division contains beds of red sandstone as well as beds with dustings of breccia; true breccias are developed thickly in the lower parts.

No gypsum occurs at the outcrop S.E. of Barrowmouth, but it has been proved in deep borings at points about a mile S. of Bell House and at Gutterfoot, St. Bees; hence it is probable that the gypsiferous phase occurs at intervals beneath the whole of the St. Bees Headland.

St. Bees Sandstone.—In the area mapped by Mr. Smith. unrivalled sections of St. Bees Sandstone occur in the cliffs of St. Bees Head between Barrowmouth and St. Bees, and in the numerous old quarries scattered along the cliff top. The beds exposed in McKay's quarry, about half a mile S.W. of Barrowmouth Farm, are from 220 ft. to 300 ft. above the base of the group, and consist of 77 ft. 6 in. of red stone quarried for building and occurring in large posts, with some pale greenish bands. Very little shale occurs here. The top 9 ft. of the rock, beneath the soil, is micaceous sandstone appearing as an irregular flaggy rock ('rammel'). This is characteristic of all exposures of St. Bees Sandstone and must be a result of weathering.

The pale greenish layers are used as flags, and have been employed in George Washington's House in the U.S.A.

The sandstone beneath this quarry, exposed between it and Barrowmouth Farm, is interstratified with more shaly layers, and some of the sandstones exhibit the contortions and 'ball-like' structures typical of alternations of sandstone and shale that have suffered readjustments before consolidation.

The sandstones are fine-grained, laminated and false-bedded, micaceous and occasionally ripple-marked, and frequently contain pellets of marl.

As far south as the Lighthouse the dip is westward, or south-westward, at from 6° to 12°; but from there to Fleswick Bay, where a fine section is accessible, the dip swings round to a southerly direction. From Fleswick to St. Bees the dip is S.S.W. at from 10° to 12°.

Whilst the highest beds exposed in the headland contain some chocolate shales, they are neither abundant nor striking. The Gutterfoot boring at St. Bees proved that (allowing for the height of the headland) from 1,200 ft. to 1,300 ft. of the sandstone series is present above the true Gypsiferous Shales in this area.

Mr. Eastwood reports that the St. Bees Sandstone, although easily distinguishable, makes little show in the tract between Whitehaven and Frizington. It occurs between the fault

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limiting the limestone inlier of Hensingham and Keekle Terrace. Though masked by drift, it is occasionally exposed in stream sections. Near Frizington it crops out in the higher part of the Rheda estate and has supplied the bulk of the building material for the Hall. A large quarry, now an ornamental pond, near the east lodge of Rheda, provides a typical section of the sandstone, here dipping south-west at 17°.

GLACIAL

The Glacial deposits in this area consist of boulder-clays and associated sands and gravels, that together mask a considerable portion of the country, but not sufficiently in all cases to disguise the general trend of the rock formations. They were due to both Lake District, or local ice, and ice travelling coast-wise from the Criffel district of S.W. Scotland.

Interesting phenomena that occurred at the margin of the two ice-sheets at the mouth of Ennerdale are described in detail in Appendix I, pp. 118–128.

Although drift conceals much of the solid geology in the country mapped by Mr. Eastwood, its extent is not nearly so great as indicated upon the old map. It presents no remarkable character, being for the most part reddish or greyish boulder-clay with occasional sandy patches and, more rarely, small masses of gravel such as may be seen near Parton.

In the area mapped by Mr. Smith the deposits consist largely of boulder-clay, the product chiefly of the Irish Sea ice-sheet.

The sandstone of St. Bees Headland proved to be mostly free from drift, with the exception of a scattering of small erratics and larger boulders and a few patches of clay that hold up surface waters. At Fleswick Bay, however, and at Rottington Common and Sandwith Newton, typical tough boulder-clay of considerable thickness is present.

The floor and flanks of the St. Bees–Whitehaven valley, as far south, at least, as the gap in the St. Bees Sandstone escarpment, are mostly drift-covered; whilst large spreads occur in the Cleator Moor–Bigrigg area.

A dissected fan-shaped spread of gravel, with the handle of the fan pointing towards Moor Row Station, caps the boulder-clay on the east side of the St. Bees–Whitehaven valley, between Hensingham and Bigrigg. The outspread fan is about 1 mile in width, and in places the deposit is quite 30 ft. in thickness.

The most striking development of glacial deposits, however, occurs on the sea-coast at St. Bees, where a lower purplish boulder-clay is overlain by a thick series of sands and gravels that form the hummocky ground at the mouth of the valley.

Here and there the gravels are capped by either one or two beds of peat with associated sands and loams; and at one point a pale red upper boulder-clay was discovered resting upon disturbed and contorted peat beds, the thrust being from seaward,

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thus seeming to show that the peats are interglacial. They are now being studied by Miss M. E. J. Chandler.

The lower boulder-clay rests upon the St. Bees Sandstone at the south end of the headland, its surface, at its highest point, where the clay is overlapped by gravels, rising to over 100 ft. above sea-level. From this point it sinks eastward to beach-level, allowing the Rottington Beck to breach the gravels. South of the old Seacote Hotel the clay rises from beneath the beach to a height of, roughly, 80 ft. to 90 ft., and sinks again below beach-level near Sea Mill, where the Pow Beck, draining the St. Bees valley, enters the sea. A little south of this point the clay rises into the cliff, exhibiting a fine section capped by gravels.

The gravels extend for about three-quarters of a mile inland along the course of the Rottington Beck; and beyond St. Bees itself, upon the east side of the main valley, to a point nearly ¾ miles from the sea.

A few patches only of upper boulder-clay were found, but quite sufficient to prove the former existence of a more extensive sheet. This occurrence of hummocky Irish Sea drift, overlying boulder-clay in the mouth of a valley, succeeded by a second clay due to a restricted re-advance of the ice-sheet, tallies with the phenomena observed at and near the mouth of the Whicham valley farther south[1]. Probably also an extra-morainic lake was held up behind the St. Bees drift.

It is hoped that the flora of the peats, when worked out, will prove whether the 'middle glacial sands and gravels' of this coast-line were the result of a great amelioration of the climate.

5. Northumberland and Durham District

Headquarters: Newcastle-on-Tyne.

R. G. Carruthers, District Geologist.

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In pursuance of the policy outlined in last year's "Summary of Progress" the revision of the Lower Carboniferous tract from Berwick-on-Tweed southwards has been continued. Mr. Fowler worked in the triangle Berwick–Norham–Goswick (Sheets 1 and 2), and Mr. Marsden took the Coldstream–Etal area (Sheet 3). The large area in Sheet 4 was divided between Mr. Carruthers (Holy Island and Lowick), Mr. Dinham (Belford and Bamburgh) and Mr. Burnett (Beadnell, Lucker and Chatton district).

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[1] 'The Glaciation of the Black Coombe District (Cumberland)' *Quart. Journ. Geol. Soc.*, vol. lxviii., 1912, pp. 441, 445.

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The general rock sequence amounts to at least 5,000 ft., distributed as follows :—

	Ft.
Lickar Coal Group - - - -	200
Limestone Group - - - - -	1,500
Scremerston Coal Group - - -	1,000
Fells Sandstone - - - - -	600
Cementstone or Tuedian Group - -	2,000–3,000
Kelso Lavas (local).	
Cheviot volcanics (Old Red Sandstone).	

The region is one of low relief, with an extensive drift covering, and there is much local complexity of structure not easily deciphered : there are notable sections of the Limestone Group on the coast round Berwick and at Beadnell, while the Cementstone Group is well seen along the bank of the Tweed and Till below Coldstream and Etal. Half-a-century ago many limestone quarries and small coal-pits were at work, but except for Scremerston Colliery, they have long been abandoned. It is doubtful if limestone will ever be wrought again on any considerable scale, the surface cover being too heavy. As to the coals, little is left of the Lickar seams, while the few that are workable in the Limestone Group are of no great account : concerning the Scremerston Coals one can be more optimistic, for there are extensive reserves still intact at shallow depths; the seams are numerous, and though generally soft and dirty should be suitable for power-gas and by-product purposes.

The original Survey field-maps were executed with remarkable care by Mr. W. Gunn between the years 1870–1880 : the lines then drawn have in the main been proved to hold good, although a few alterations and several additions of some moment have been made, chiefly by the use of palæontological data. Particular attention has been paid to the indication of promising areas of the Scremerston Coals, and to discover characteristic features, or "marks," of service in recognising definite horizons when boring through the supervening Limestone Group.

Old Red Sandstone.—Mr. Marsden reports that in the area of Cheviot lavas N. of the Bowmont Water, it has been impossible to map out individual flows owing to the uniformity of rock-type : in general, the andesites south-west of Howtel often show black mica, and the rock is distinctly redder than in the country to the north. The lavas are much decomposed at their junctions with the Cementstone Group near Milfield, and evidently there was much subaerial denudation before the Carboniferous rocks were deposited. The absence at Milfield of both the Kelso Lavas and the Carham Limestone is no doubt due to overlap on to the Cheviot massif.

Cementstone Group.—It has long been known that in the excellent sections along the valleys of the Tweed and Till, these strata are of a pronounced estuarine character, *Naiadites*, ento-

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mostraca, and *Spirorbis*, along with plant debris, being particularly abundant; in this respect they differ from the Liddesdale exposures on the west of the Border, where purely marine fossils are not uncommon. Mr. Marsden, however, has noticed *Syringopora* in the Tweed section north of Brownridge, on the east bank of the Till opposite Old Heaton, and again at Broombridge Dean, east of Kimmerston. In the Cornhill district, from material collected by Mr. Marsden, Dr. Kidston has been able to identify *Lepidodendron nathorsti* and *Adiantites antiquus* from shales in the Willow Burn, ½ mile S.W. of West Learmouth, and there is hope that with further collecting considerable additions may be made to our scanty knowledge of the plant life in these rocks.

Scremerston Coal Group.—A complete record of this series, as developed around Scremerston itself, was obtained in 1914–15 from three diamond bores put down for the Director of Greenwich Hospital. The cores, which were in a very complete state, were examined at the time by Mr. Carruthers; pending a complete account of this matter it may be noted that the whole group from the Dun Limestone down to the top of the Fells Sandstone, proved to be some 1,080 ft. thick: there were at least 10 coal seams (some over 2 ft. thick), the best of these being the Scremerston Main Coal, as follows :—

Section of the Main Coal in No. 1 Bore, Scremerston.

	Ft.	in.
Roof. Soft grey shale	—	—
Coal	2	6
Hard Grey shale		8
Sandstone, rib, hard, and with entomostraca at the top	1	1
Foul Coal		10
Dark grey limy ironstone, with pyritised entomostraca and gasteropods	1	3
Coal	2	6
Pavement. Sandy shale and fireclay.		

The only fossils in the Scremerston Group, either in these borings or elsewhere, as noted by previous observers, are of estuarine or freshwater character (*Naiadites*, entomostraca, *Spirorbis*, small gasteropods, and comminuted plant debris). Mr. Marsden, however, has noticed in Duddo Mill Burn, near Etal Colliery, a 9-in. limestone with crinoidal debris, about 50 feet below the Fawcet Coal; 5 ft. below this is a 10-in. coal, interbedded with which are shaly partings yielding *Fenestella*, and small crinoid ossicles along with *Spirorbis* and *Naiadites*. North of this exposure the limestone is again visible in the old clay pit at Duddo Tile Works.

The Scremerston Coals undoubtedly improve in a northern direction both in thickness and quality. It is quite possible that they may be in good state below the covering fringe of higher strata along the coast north of Berwick, where Mr. Fowler has been able to confirm Mr. Gunn's correlation of the Lamberton or Marshall Meadows Limestone with the Dun, *i.e.*, the limestone immediately overlying the Coal Group. The strata lie practically

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flat hereabouts, but most of the seams would have to be wrought undersea.

South of Belford, Mr. Burnett has examined the well-marked anticline of the Scremerston Group, south-west of Twizell House: the Fawcet Coal has been wrought on either side of the fold, but the Main Coal and lower seams do not outcrop, though they must be very close to the surface. This unproved area should be worth attention in the future, and also the ground E. of Commonflat, where strata below the Dun Limestone are seen in the Priest Burn at least as far east as the main road to Alnwick.

Limestone Group.—Within this group there are, in North Northumberland, at least 16 distinct bands of crinoidal limestone, ranging from the Great or Dryburn Limestone down to the Dun and distributed through some 1,500 ft. of strata. The sequence has been detailed by Mr. Gunn in various publications, especially in the Memoir on 'The Geology of the Coast south of Berwick-on-Tweed.' Although the series is equivalent to the Lower Limestones, together with at least the upper half of the Oil-shale Group of Scotland, as a matter of fact only one oil-shale of the Lothian type is known, that of the Doubster Burn, near Scremerston. The individual limestone bands, though thoroughly marine, differ somewhat from the Scottish ones in that the overlying shales are generally poor in fossils, and the limestones themselves often rest directly on the coal beneath, without the intervention of an 'estuarine' shale; quite commonly indeed, there is an actual interbedding of crinoidal limestone or shale with coal, which in such cases may be, in part at least, a true drifted deposit.

The fine shore sections at Spital, south of Berwick, have been measured by Mr. Fowler, and those at Beadnell by Mr. Burnett; they have proved of great value as standards of reference. Although fully 18 miles apart, these two sections agree remarkably well, the 13 limestones between the Dryburn and Oxford at Beadnell all reappearing at Spital with but little change. Using the Spital section for the interpretation of the coast section north of the Tweed, Mr. Fowler has been able to identify both the Doubster Oil-Shale and the Oxford Limestone at Calot Shad, south of the breakwater; again, in the synclines farther north at Bucket Rocks and Greens Haven, he has recognised the Eelwell Limestone, 27 ft. thick; and north of the Greens Haven fault the Oxford Limestone, 14 ft. thick. These readings are all new, for although the sections are easily accessible, little work seems to have been done on them.

On Holy Island, Mr. Carruthers finds that the limestone seen on the shore south of the Cathedral ruins, previously mapped and described as the Lowdean or Sandbanks Limestone, should be referred to the Acre. In North Northumberland, the shale immediately overlying the Acre Limestone is of a highly characteristic nature; not only are the fossils remarkable for their variety and good preservation, but certain of them (a small

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narrow variety of *Cyathaxonia cornu* and a new species of *Caninia* akin to *C. cornucopiæ*, are restricted to this horizon. It is worthy of remark that precisely the same assemblage is found in Scotland above the middle Skateraw Limestone at Dunbar, whose identity with the Acre can be inferred from Mr. Gunn's table of correlations.[1] The Holy Island exposure of the Acre shale, seen immediately east of the lifeboat house south of the Cathedral ruins, is complete and typical.

On the mainland, opposite Holy Island, an important correction has been made in the reading of the ground round Fenwick. A limestone formerly wrought at the steading east of the Berwick main road was referred to in the Memoir on the Belford District as 'probably one of the higher limestones (Eelwell or a higher one).' There can be little doubt, however, that it is in reality the Dun Limestone, a thousand feet or more below the Eelwell; not only is the general character strongly reminiscent of the Dun, but the shale above has yielded a large finely-ribbed *Productus*, *Zaphrentis lawstonensis*, and a polyzoan identified by Dr. Lee as *Tabulipora howsei*, all these being fossils characteristic of the Dun position. The limestone at Fenwick Granary, north of this, though mapped as the Watchlaw, is more probably the Woodend, with which it is in agreement lithologically, and also in the presence of a coal seam a few feet above. A large fault running alongside the Berwick road, down south-east, must separate this tract from the higher strata seen to the west. Since the Scremerston Coal Group directly underlies the Dun Limestone, these alterations in the mapping have a distinct economic value.

Some modification has been made near East Kyloe, where the limestone crossing the stream west of the hamlet is in the Dun, not the Woodend, position.

In the Belford–Bamburgh area, revised by Mr. Dinham, there is a great deal of drift, and the few rock sections both on the coast and inland, are of a fragmentary nature. In the search for characteristic features amongst the limestones, attention was paid to certain porcellanous-looking haloes, surrounding fragments of fossils, which were previously recorded by Professor Garwood from the Oxford Limestone[2] and later ascribed by him to *Girvanella*.[3] In the Belford district, and indeed over the whole of North Northumberland, these *Girvanella* nodules are a special character of the Oxford position; the only other limestone in which they are at all conspicuous is the Dun, where, however, they are decidedly less numerous. As an example of their use in the interpretation of doubtful ground, the limestone of Elford Quarry can now be definitely assigned to the Oxford.

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[1] W. Gunn, 'Notes on the correlation of the Lower Carboniferous Rocks of England and Scotland,' *Geol. Mag.*, 1898, p. 348. The correlation is given in the text (p. 347), where it is ascribed to Mr. James Bennie.

[2] In Bateson's 'History of Northumberland,' vol. i., 1893.

[3] *Quart. Journ. Geol. Soc.*, vol. lxviii., 1912, p. 547.

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The shales overlying a limestone in Budle Bay, west of Bamburgh, have long been known for their abundance of *Posidonomya becheri*. This lamellibranch is rarely found in English Carboniferous Limestone strata though common in the over-lying shale series (Pendlesides). It had been recorded in Northumberland from one or two other limestones of doubtful horizon, and is so easily recognised that an effort was made to test its value as a stratigraphical index. The inquiry showed that the *becheri* shales of Budle, Easingtongrange Mill and Glororum quarries, probably belong to the 3rd limestone above the Oxford. Mr. Burnett has also obtained the shell from the same horizon on the Beadnell coast, and in the Long Burn at Tugganmill and at Fleetham. This, however, is by no means the only level at which *P. becheri* was found; it was noticed in fair abundance in a similar tough mudstone at Greenhill Rocks, Bamburgh, overlying the first limestone below the Oxford, and rare specimens were collected from shales over the Oxford Limestone itself; in the quarries north-west of Elford and west of Easington Demesne. These occurrences discount the use of the shell as a stratigraphical guide, though it may perhaps have some local value.

In the Belford district and to the south of Mounthooly, Lowick, a new marine horizon was noticed above the Upper Howgate Coal.

The quartz-dolerite intrusion known as the Whin Sill is prominent in the Belford country, where it forms a stepped series of escarpments, regarded by Mr. Gunn as separate intrusions at distinct stratigraphical horizons. There is considerable evidence that such appearances are often better ascribed to abrupt transgressions of a single sill, in much the same manner as the quartz-dolerite sheets behave in the Central Valley of Scotland.

In the Beadnell-Ellingham district Mr. Burnett reports that while little change is needed in the reading of the limestones, some modifications have been made in the fault lines; much of the structure of the ground is obscure, and more work is required to clear up doubtful points. Mr. Gunn considered that the coals wrought long ago at Coldrife Colliery were most probably the Lickar seams; there is, however, good reason to think that they represent the Howgate Coals, lying between the Oxford and Woodend Limestones.

Lickar Coals.—The two small synclines of this series at Lickar and Berrington have long been exhausted. Further areas may exist in the low ground W. of Goswick, but the coals do not reappear to the south until we reach Brunton, south of Ellingham; where, in the stream above the railway bridge, Mr. Burnett has noticed abundant fragments of a striped blackband ironstone practically *in situ*. This may perhaps be the equivalent of the so-called 'oil-shale' at Berrington and Lickar, which is a micaceous 'parrot shale,' such as is usually associated with blackband ironstones elsewhere.

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Glacial Deposits.—There are two kinds of boulder clay in North Northumberland, one a stiff dark clay, crowded with local rocks, the other a red clay with much finer material, and of more distant origin. The relationship of these clays to one another is well seen in the low cliffs at the south end of Holy Island, particularly west of the village. The dark clay lies at the bottom and is a true ground moraine, packed with local rock debris. Some of the sandstone lenticles, though only a foot or so thick, are as much as 20 yards long. They seem to have been frozen in and dragged along the sole of the ice-sheet, since they are horizontally disposed, and, though unbroken themselves, rest among highly contorted rock debris. The overlying red clay shows no such signs of movement, and between the two clays is a parting of sand and gravel, quite undisturbed. Similar sections are to be seen on the east side of the island opposite Broad Stones.

These phenomena seem to be strictly comparable with those observed by Mr. Lamplugh in 1910,[1] where the conjunction of two dissimilar clays was shown to be due to the melting of a single ice-sheet, resulting in a quiet setting-down of the included and superficial debris on to the ground moraine. This interpretation of the Holy Island sections may apply to much of the boulder clay areas of North Northumberland, where the two clays are known and are accompanied by thin sheets of sand and gravel whose origin has hitherto been somewhat obscure.

The investigation of the so-called 'kames' at Wark and Pallinburn in the Tweed Valley, and at Bradford and Lucker south-east of Belford,[2] is still proceeding, as is that on the 'glacial lake' in Glendale and the Till Valley.

Mr. Marsden has been able to show that the small 'inliers' of Kelso Lavas at Wark West Common and east of Sunnylaws are probably large erratics, or accumulations of erratics, carried eastward from the main outcrop above Carham.

(B)—SCOTLAND

Coalfield Revision

1. Ayrshire Coalfield

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Mr. Anderson and Mr. Richey were employed in North Ayrshire, in one-inch map Sheet 22. They made substantial progress

[1] G. W. Lamplugh, *Proc. Yorks. Geol. Soc.*, vol. xvii., pt. iii., 1911, pp. 237—8.

[2] Recently dealt with by Professor Gregory in a paper on 'The English Eskers,' *Geol. Mag.*, Jan. 1922, p. 25.

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in matters of detail in regard to all divisions of the Carboniferous, from the Clyde lavas to Coal Measures inclusive. Mr. Eyles and Mr. Simpson started the revision of Central Ayrshire, on the junction of Sheets 14 and 22.

Millstone Grit Volcanic Zone, N. of Adamhill.—On the published one-inch map Sheet 22 'trap-tuff' is shown between the Coal Measures and Carboniferous Limestone Series in a roadside stream exposure east of Townend marked C on Fig. 2. The rocks consist of rotted olivine-basalt and bauxitic clay, and it has been recognised for some years past that they represent the top of the Millstone Grit volcanic group, including some

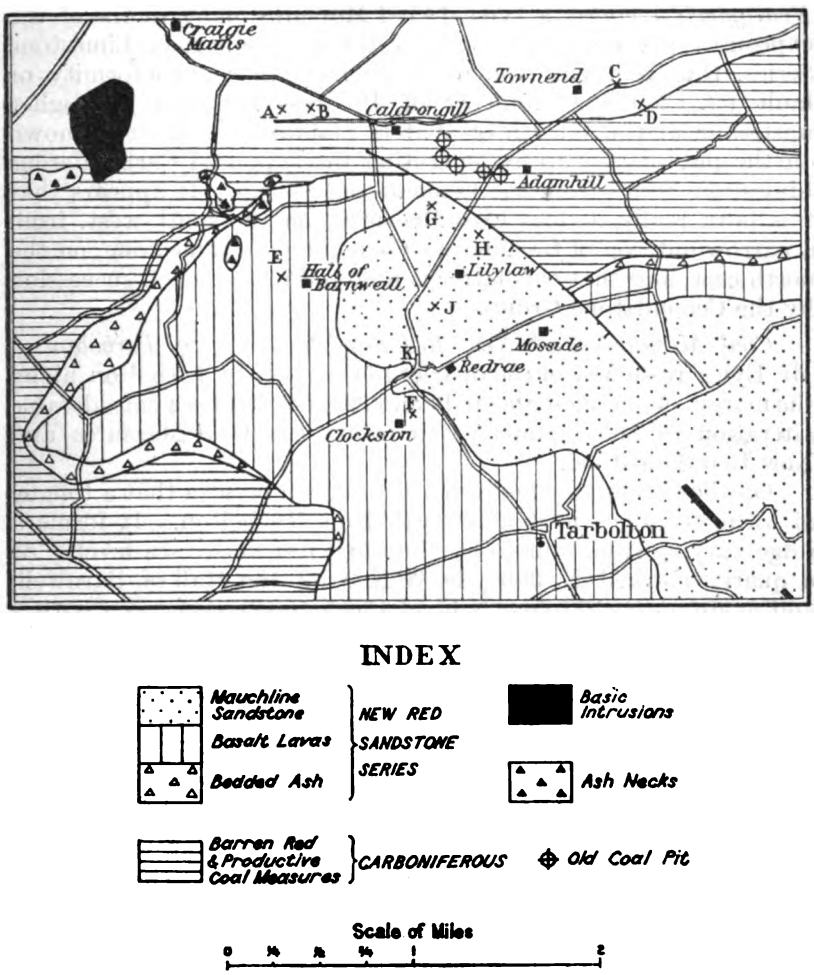

FIG. 2.—*Geological Map of the Tarbolton District.*

Ayrshire Bauxitic Clay. Mr. Eyles has found further exposures of rotted olivine-basalt at D, 375 yds. down-stream from C; and at A, in a small burn 200 yds. south of the road between Caldrongill and Craigie Mains. He has also met with volcanic

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mud at B, in another burn 200 yds. east of A. The exposure at D, and with less certainty those at A and B, are here referred to the Millstone Grit volcanic group, and a tentative line for the base of the Coal Measures is drawn accordingly on Fig. 2.

From the evidence available the bauxitic clay is very ferruginous and of poor quality.

Coal Measures and Carboniferous Limestone, N.W. of Sorn.—In Sheet 14, 2 miles north-west of Sorn, Barren Red Coal Measures are mapped unconformably lying on some part of the Carboniferous Limestone Series. In the Burn o' Need, a tributary entering the River Ayr at Catrine, Mr. Simpson has found *Neuropteris gigantea*, a typical Coal Measures plant, in one of the exposures previously referred to the Carboniferous Limestone Series, thus removing the necessity for either unconformity or fault (*cf.* Clough, 'Summary of Progress for 1909'). Higher upstream, at the Wealth of Waters plantation, a fault is shown on the published map as separating the supposed Carboniferous Limestone Series from the Cementstone Group. It appears that this fault really divides Coal Measures, on the south-west, from a narrow outcrop of fossiliferous Carboniferous Limestone, on the north-east, and that this latter is followed in unbroken succession by the Cementstone Group.

Coal Measures and New Red Sandstone, N. of Tarbolton.—Mr. Eyles' re-survey of the district to the north of Tarbolton, along the margin of one-inch Sheets 14 and 22, necessitates a considerable alteration of the boundary separating the Coal Measures and New Red Sandstone.

On the accompanying sketch map it will be seen that a tongue of lavas stretches west and north from Tarbolton. It forms a ridge varying from four to five hundred feet above sea-level. At a quarry marked E, 300 yds. W.N.W. of the Hall of Barnwell, and again at F, 100 yds. N.E. of Clockston, lava is seen with a gentle easterly dip; and, in fact, the eastern side of the ridge is shown by these exposures to approximate to a dip-slope. This, in itself, is a contradiction of the old reading, for, whereas the east face of the ridge was previously interpreted as a dip-slope as far as Clockston, it was treated as an escarpment in the neighbourhood of the Hall of Barnwell.

The area in which alteration is involved lies north and north-east of Redrae. Formerly the lava outcrop, shown on Fig. 2 as terminating east of Mosside, was continued in a straight course through ground without exposures, to join the Tarbolton outcrop at Redrae; and the sandstone exposures at G, H, J and K were mapped as Barren Red Coal Measures. These sandstones, however, with their orange-red colour and the wind-rounding of their larger grains, exactly resemble the New Red Sandstone and are totally unlike the Barren Red Coal Measures. Accordingly they are shown in Fig. 2 as continuous with the New Red Sandstone of the Mauchline basin, and as overlying the lavas which, at the Hall of Barnwell, are clearly seen to dip towards

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them. Their north-east boundary is not exposed, but must be a fault. On this interpretation of the structure the depth to coal round Lilylaw is increased to the extent of the thickness of the New Red Sandstone and lavas of this district.

New Red Lavas and Sandstone, Mauchline.—Mr. Simpson describes the lavas which underlie the sandstones and rest on the Barren Red Beds of the Coal Measures as fine-grained micro-porphyritic olivine basalts with a fair amount of lithological variation. A good section is exposed on the R. Ayr, between Catrine Holm and Howford Bridge. The outcrop is made up of many thin lava flows, which usually have well-marked slaggy upper portions. At several points small intercalations of sandstone occur with large rounded grains exactly similar to the overlying New Red Sandstone.

The last phase of the volcanic episode was marked by the outpouring of tuff, very well seen in the R. Ayr, immediately below the Howford Bridge. It is here seen that the upper portion of the tuff contains numbers of rounded sand grains about the size of millet seed, which become more numerous towards the top, where thin beds of sandstone are interleaved with tuff. Isolated patches of tuff occur in the first few feet of the New Red Sandstone, and one lenticular patch was noticed at least thirty feet above the unbroken top of the tuff proper.

On the Mauchline–Catrine road, $\frac{3}{4}$ mile west of Mauchline, new exposures of lava have been noted which necessitate the drawing of the boundary between the lavas and the Barren Red beds 300 yds. farther east than is shown on the old map.

Half a mile to the east of the farm of Brigland in the Barren Red beds, and about three-quarters of a mile N.E. of the lava scarp, an outcrop of basalt similar to the Mauchline lavas is exposed in the form of a circular knoll. No boundary is visible, but it appears to be a plug in a neck, several of which are known outside the main lava outcrop.

Mr. Simpson has found that locally the New Red Sandstone of Mauchline is cut by fairly numerous large basic igneous dykes, few of which have been previously recorded. Within about three miles west and two miles south of Mauchline Station there are some eight dykes exposed running in various directions between N.N.W. and W. 20° S. For comparison with the E. and W. quartz-dolerites of the Forth Basin, two examples with an E. and W. trend were sliced, and were found to be olivine-dolerites of Tertiary type.

Glacial.—The common occurrence of shelly clays, not assignable to late-Glacial or post-Glacial raised-beaches, is a feature of the geology of Central Ayrshire that has attracted considerable attention in the past.[1] Additional instances have been met

[1] *Cf.* John Smith, in 'The Drift or Glacial Formation of the Clyde Drainage Area'—Fauna, Flora and Geology of the Clyde Area (Handbook for British Association, Glasgow), 1901, p. 526.

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with during the past season by Mr. Eyles, who records a particularly good exposure in a burn 100 yds. north of Alton Lodge, on the main road midway between Ayr and Mauchline. Here shelly clay is discontinuously exposed over a total length of 350 yds., with a breadth of at least 50 yds., and at elevations from 250 to 300 ft. above O.D.

The clay is very stiff and fine-grained. It contains no boulders and only occasional small pebbles, not always of local origin. It is usually pale greenish grey, but in places blue-black, weathering brown. It shows distinct stratification in its upper layers, and is certainly an aqueous deposit.

The shells are mainly bivalves. They were kindly determined by Dr. James Ritchie of the Royal Scottish Museum, who found that they represent an arctic marine association.

The larger bivalves are always present as fragments, and sometimes broken pieces of a single valve are found in contact as if crushing had occurred during a disturbance of the containing clay. In other cases the fragments are isolated. The smaller shells are often perfectly preserved, retaining the epidermis, and in one or two cases both valves of a bivalve have been found together. The attitude of the shells in no case suggests that they were alive while the clay was being deposited.

Red boulder-clay occurs in the neighbourhood, and almost certainly overlies the shelly clay.

It must not be thought, however, that the shelly clays of Central Ayrshire are usually aqueous deposits. More often they are boulder-clays. Mr. Simpson has supplemented previous records from the Sorn and Ochiltree district by finding shell fragments in practically every exposure of Boulder Clay in the Bogend Burn of Catrine from 300 to 400 ft. above O.D. At one place, about 150 yds. upstream from where the railway crosses the burn, blue-grey silt is seen, about 330 ft. above O.D., overlain by boulder-clay. The silt is very rich in shell fragments lying at all angles, and is itself unbedded so far as can be seen in the small available exposure.

As bearing upon the possible source of the shells, it is interesting to note that Mr. Simpson has at one point found evidence suggestive of glacial carry from the west or south-west. In a stream-section through boulder-clay north of Auchmillanhill (N.E. of Mauchline), striated boulders are exposed which seem to have been derived from the lava group at the base of the New Red Sandstone to the west.

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2. Muirkirk and Lesmahagow, Stirlingshire, and Clackmannanshire

Muirkirk District

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Mr. Wilson began the revision of the Glenbuck–Muirkirk area. Most of the field work was carried on among the older rocks north of the fault which forms the northern margin of the coalfield. This fault is probably a continuation of the fracture which extends south-westwards from Cronberry through Old Cumnock to the coast near Girvan.

Pre-Carboniferous Rocks.—The lowest members consist of Silurian shales and greywackes overlain in conformable succession by red, purple, and buff-coloured sandstones and marls of Downtonian age. The general dip of these rocks is to the north-west at angles varying from 20 to 70 degrees; locally the dip changes to the south-east, while, at the head of the Ponesk Burn, flat or rolling strata occur. The Upper Old Red Sandstone rocks are best developed near Middlefield. They have a total thickness of 500 to 600 feet, and consist of variegated sandstones and marls, showing purple, greenish, and yellow tints, with associated beds of cornstone. These latter may reach 20 or 30 feet in thickness and were formerly worked on an extensive scale at Middlefield quarries. The unconformable junction at the base of this series is seen in the Harwood and Burnfoot burns, where the Upper Old Red dips southwards off the underlying Downtonian. Farther east the dip changes to west, and where the unconformity is next exposed, on the south side of the Greenock Water, the underlying rocks are of Silurian age and the Upper Old Red Sandstone is dipping north-west.

Calciferous Sandstone Series.—In the centre of the basin of Old Red Sandstone rocks, the axis of which coincides roughly with the course of the Greenock Water, a good development of the Cementstone Group is found. Numerous exposures of soft grey marly fakes with occasional bands of cementstone are to be seen in the Harwood, Burnfoot and Mossy burns.

Igneous Rocks.—The main igneous rock of the district is the large intrusion of porphyritic felsite which extends along the northern margin of the boundary fault for a distance of several miles. This intrusion is later than the Old Red and most probably earlier than the Carboniferous Limestone.

A few small vents probably of Permian age occur, consisting of very basic and greatly decomposed tuff-like materials with large crystals of hornblende and biotite.

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Several north-west dykes of Tertiary type were noted. At a quarry at the side of the abandoned railway near Pauper Craigs an excellent example of one of these is seen cutting through the material of a volcanic vent.

Pleistocene and Recent.—The various stages in the retreat of the ice westwards down the valley of the Greenock Water are well illustrated in the country between the Dippal Burn and Glenbuck. It is clear from the topography that the great gorge of the Ponesk Burn is a late-Glacial feature, and that prior to its excavation the water flowed almost due westwards to join the Greenock Water near Blackside. The phenomena of retreat manifest themselves in a remarkable series of marginal and overflow channels, most of which except for insignificant streams are now practically dry. No. 1, the highest so far noted, has its intake on the divide between the headwaters of the Dippal and Patrick burns, and runs for over half-a-mile along the south-west shoulder of Priesthill Height at about the 1,300-foot level. On the south slopes of Starpet Rig again occurs a well-marked succession of marginal channels; three of these (Nos. 2, 3, and 4 of Fig. 3) are each about half-a-mile long and two of them

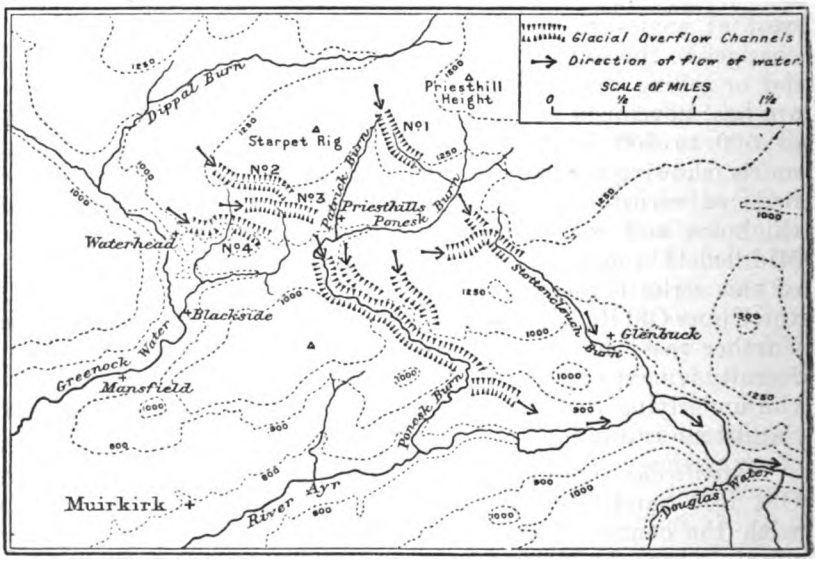

FIG. 3.—*Map showing Glacial Overflow Channels near Muirkirk.*

attain a depth of 100 feet or more. The intake of No. 2 lies at an elevation of about 1,275 feet. All these appear to have debouched into temporary glacial lakes held up along the front of the ice which blocked the Greenock valley and in the early stages at least also filled the Priesthills hollow. The drainage from these escaped in all cases south-eastwards into the Douglas valley by a well-defined series of overflow channels. Thus the waters of Nos. 1 and 2 marginal channels found outlets into the present Stottoncleuch Burn by two overflows cut at slightly

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different levels. The material removed during the excavation of No. 2 has been built up into a large steep-fronted deltaic deposit lying just west of Priesthills. No. 3 channel, formed when the ice-front to the west stood at a level of about 1,150 feet, is only 20 to 30 ft. deep except at its lower end where it has cut a deep gorge through the delta fan of No. 2. Its waters and those of the conspicuous lower marginal cut marked No. 4 in Fig. 3 escaped south-eastwards by cutting a new overflow channel along what is now the lower part of the Ponesk Burn. The great gorge of this burn, over a mile long and up to 200 feet deep with almost vertical walls of felsite in places, served as a line of escape for the enormous volumes of water released during the later phases of retreat.

In this brief account only the main drainage channels have been mentioned. It should be added, however, that in the cases of Nos. 3 and 4 two or three subsidiary retreat stages can be made out. The drainage channels associated with these have intakes 10 or 20 feet below those of the main ones, but they do not extend far, the waters eventually finding their way back into the latter.

Lesmahagow District

Old Red Sandstone.—Mr. Ross completed the revision of the area of Lower Old Red Sandstone rocks on the north side of the Douglas coal basin and began a re-examination of the Carboniferous sediments. The former consist chiefly of massive red sandstones, mottled purple and red flags and subordinate marly bands. The best exposures are seen in the headwaters of the Linn Burn and in the River Nethan near Boughden Braes and Brownhill. The dip varies from E. to E.S.E. at angles of 12 to 35 degrees. A band of conglomerate, containing pebbles of greywacke and red chert, has been traced along the west slopes of Clarkston Strip and Hilltop Wood, the best section occurring in an old quarry east of Dillar's Corner. A number of intrusions of felsite and of quartz-porphyrite formerly quarried for road-metal have been mapped. The intrusions are inclined in the direction of the dip in the associated sediments, which they seem to cut at low angles.

Carboniferous.—From near Gateside south-westwards for some 3 miles the fault forming the boundary between the Old Red and the Carboniferous keeps close to the western bank of the Nethan. The examination of this faulted belt has been commenced, but the working out of the detailed local sequence from the broken and partial sections available has not been completed.

The ground is largely covered with drift of a sandy and gravelly nature. Where good sections are exposed this is seen to pass downwards into stiff, clayey material resembling the typical boulder-clay of other districts, and containing numerous fragments of greywacke, chert, and other Southern Upland

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types, many of which, however, may be derived at second-hand from the conglomerate bands in the Old Red Sandstone.

Several borings for coal have been visited and examined.

STIRLINGSHIRE

Mr. Read has revised the area lying along the Forth from the face of the Ochils at Bridge of Allan and Blairlogie southwards to Stirling.

Lower Old Red Sandstone.—In order to complete the revision of the six-inch sheets for publication Mr. Read has begun the mapping of the western part of the Ochils above Bridge of Allan, Airthrey Castle and Blairlogie. The great Ochil Fault which in this area forms the southern boundary of the volcanic and sedimentary rocks of Lower Old Red Sandstone age is, from Alva westwards, concealed beneath the carse clays or beneath gravels of the '100-ft.' beach. The general direction of the Ochil Fault can, however, be inferred as about E.N.E.–W.S.W. The fault passes through Menstrie, just S. of Blairlogie, N. of the Abbey Craig and so to Cornton. Further westwards along its line, chocolate coloured sandstones of Lower Old Red Sandstone age are seen in the banks of the Forth at Craigforth Mill, whilst, about half-a-mile to the south, lavas of Calciferous Sandstone age make Craigforth Hill, rising from the level Carse plain. The Ochil Fault runs between these two localities.

The Lower Old Red Sandstone rocks of this part of the Ochils consist of andesite lavas, extremely coarse agglomerates, conglomerates and sandstones, dipping a few degrees west of north at angles of 9° to 12°. They are cut up into blocks by large faults, which run in a general N.N.W.–S.S.E. direction. The downthrow is generally to the west, so that, for example, the lavas seen on the top of Dumyat (1,378 ft.) above Blairlogie, are, in a distance of less than a mile, thrown down to the level of the Carse edge (50 ft.), whilst, a little further west, they are faulted out of sight altogether. Above Blairlogie these N.N.W.–S.S.E. faults are often the sites of broad barytes veins, as described by Mr. G. V. Wilson.[1]

Upper Old Red Sandstone.—Near Spittal, at Causewayhead, alongside the Bridge of Allan road, there is an old quarry in false-bedded sandstone, usually mottled red and white, but in places greenish. Less conspicuous are thin bands of very coarse grit, sandy shale and a marl with white cornstone concretions. The rocks seen are exactly like those of Upper Old Red Sandstone age occurring below the Cementstones in the burns south of Gargunnock on the north side of the Campsie Hills. The quarry must lie south of the main Ochil Fault.

At Spittal, however, nothing is seen of the Cementstone Group or of the great volcanic series of the Campsie Hills, but

[1] 'Special Reports on the Mineral Resources of Great Britain, vol. ii., Barytes and Witherite' (*Mem. Geol. Surv.*), 1922, ed. 3, pp. 107, 108.

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in a nearly obscured quarry in the grounds of Abbeycraig Park, some 200 yards east of the Spittal quarry, there occurs a series of rocks, described in detail below, which are doubtless part of the Lower Limestone Group of the Carboniferous Limestone. The current view[1] appears to be that the Calciferous Sandstone lavas of the Campsie Hills have thinned out at Causewayhead; they are last seen on the Craigforth 'island' already mentioned. But what evidence there is appears to point to a faulted junction of the Upper Old Red Sandstone against the Lower Limestones at Causewayhead, for, in a garden, half way between the Spittal and Abbeycraig Park quarries, there is a small crag of whitish slickensided sandstone, much-broken fakes and squeezed fireclay, which all have the appearance of a fault-rock. The Spittal Upper Old Red Sandstone may therefore lie between the main Ochil Fault and another a little to the south, and the Campsie lavas may be thrown down out of sight.

Carboniferous.—Little is seen in the area of the Carboniferous sediments beneath the Stirling sill,[2] which forms the Abbey Craig on the north of the Forth, and the crags of Stirling Castle and the King's Park on the south.

At Abbey Craig the base of the sill is not visible; the neighbourhood of its top may be indicated by a finer-grained type of dolerite occurring in a quarry on the east side of the Craig, 300 yards north of Craigmill.

On the west, no rocks are exposed for some distance below the lowest visible part of the sill until the Abbeycraig Park quarry, already mentioned, is reached. Mr. C. H. Dinham measured the section some years ago and, since the quarry is now inaccessible, the following record is given :—

	Ft.	in.
At the top, limy looking blaes	1	3
Faky LIMESTONE, some brachiopods, but fossils not well preserved or common	–	8
Solid blue LIMESTONE, weathering bright yellow, with fossil fragments throughout, though chiefly showing on weathered surfaces. Small encrinites, fragments of Athyrids, Productids, &c.	1	2
Faky LIMESTONE, yellowish weathering, grey with reddish brown streaks	–	4
Gap, probably fakes or blaes, about	–	6
Rotten sandy faky fireclay with red patches	–	4
Coarse quartzose sandstone, with some quartz pebbles more than ¼ in. long, in thick posts with occasional partings only, at least 30–36 ft.		

These rocks undoubtedly belong to the Lower Limestone Group, and the sill at Abbey Craig most probably is intruded into the Limestone Coal Group.

[1] H. W. Monckton, *Proc. Geol. Assoc.*, vol. xii., 1892, p. 243; Sir Archibald Geikie, *Trans. Roy. Soc. Edin.*, vol. xxix., 1879, p. 450; also 'Ancient Volcanoes of Great Britain,' vol. i., 1897, p. 384.

[2] H. W. Monckton, *loc. cit.*, p. 202; *Quart. Journ. Geol. Soc.*, vol. li., 1895, pp. 480–492.

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Beneath the Stirling Castle portion of the sill, the junction of the dolerite with the underlying sediments was formerly visible at a point N. of Ballingeich Cemetery, where, beneath the chilled margin of the intrusion, there occurred 'calmstone' or hardened shales.

At Ballengeich Pass, about 240 yards E. of Raploch School, the following section may be seen :—

	Ft.	in.
Faky sandstone and sandstone, top not seen	3	6
Dark blue parroty micaceous fakes, with many fish scales and teeth, and some poor *Lingula*	–	6
Bright Coal	–	4
Coaly sandy fireclay	–	1–2
Coal	–	1
Coaly fireclay	–	2
Faky sandstone, with irony balls	4	2
Black blaes and few ironstone balls	2	7
Faky sandstone, varying from 1½ ft. to	3	6
Sandstone	3	6
Dark grey, thin-splitting fakes	1	11
Ironstone band	–	1
Grey fakes	–	4
Fakes and faky blaes	5	6
Nodular limestone band	–	2–3
Fireclay	–	5
Coal, bright	–	1
Fireclay	1	–

The section of the upper coal, with the fossiliferous parrot above it, is extremely like that of the Milton Coal of Bannockburn as observed by Mr. C. H. Dinham in the Bannock Burn, at Milton, The Milton Coal lies some 20 fms. below the Black Metals in the Limestone Coal group.

From bores around Raploch, it appears that there is a considerable thickness of strata, probably including the whole of the Lower Limestone Group, below the Stirling sill in that neighbourhood.

No sediments are seen beneath that part of the Stirling sill which forms the crags of the King's Park.

From the evidence given above, it appears probable that at both Abbey Craig and Stirling Castle, the sill is intruded in the Limestone Coal group a short distance below the Black Metals. Mr. Dinham[1] has shown that in the Bannock Burn, 4 to 5 miles S.S.W. of Stirling, the base of the sill lies about 14 fms. above the Murrayshall (Hurlet) Limestone. The difference in stratigraphical level of the intrusion at these two points is, roughly, 100 fms.

Raised Beaches.—From Bridge of Allan to Blairlogie Church the coast line of the '100-ft.' beach is well marked at a level of about 140 ft. Southwards from this coast line at Airthrey to the Abbey Craig 'island' there stretches a much-dissected flat-topped terrace of brownish sandy gravels. Two small islets of boulder-clay stood out of the '100-ft.' sea to the north of Causewayhead.

[1] 'Summary of Progress' for 1919 (*Mem. Geol. Surv.*), 1920, pp. 35–40.

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During Carse times the Abbey Craig was connected with the Airthrey 'mainland' by these '100-ft.' deposits. The flat clay grounds of the Carse have their margin at 50 ft. and extend into many old bays such as those at Touch House, Cambusbarron, King's Park Farm and east of the Abbey Craig.

Clackmannanshire

Mr. Haldane continued the revision of the ground lying to the east of Alloa. Many fresh exposures of coals, opened along outcrops during the strike of April to June, were noted.

The following is a composite general section of the strata below the Coalsnaughton Main Coal (4 ft. thick) and should be read as a continuation of the vertical section of the Clackmannanshire coalfield, published by the Geological Survey in 1877 :—

	Thickness Fms.	ft.	in.	Depth. Fms.	ft.	in.
Coalsnaughton Main Coal	–	–	–		—	
Blaes	–	–	9		—	
Sandstone	2	5	–		—	
Fakes and blaes with a 9-in. sandstone rib	1	5	10		—	
Coal	–	–	8	5	–	3
Faky blaes	–	2	8		—	
Sandstone	1	4	3		—	
Fakes and blaes	–	5	3		—	
Coal ('Mid Cherry' or 'Mill')	–	2	1	8	2	6
Faky blaes	1	2	5		—	
Sandstone	1	4	8		—	
Faky blaes	–	5	11		—	
Fireclay	–	–	4		—	
Coal	–	–	7	12	4	5
Coaly blaes	–	–	2		—	
Faky fireclay	–	4	6		—	
Sandstone	1	–	6		—	
Fakes	–	–	6		—	
Coal	–	–	6	14	4	7
Coaly blaes	–	–	3		—	
Fireclay	–	5	8		—	
Sandstone	6	3	8		—	
Fireclay	–	–	8		—	
Coal	–	–	9		—	
Faky rib ('Lower Splint' or 'Ball')	–	–	5		—	
Coal	–	2	3	23	–	3
Fireclay and fakes	–	1	8		—	
Sandstone	–	2	9		—	
Fakes	–	–	2		—	
Ironstone ball	–	–	3	23	5	1
Shaly blaes	–	1	6		—	
Sandstone	4	3	5		—	
Fireclay	–	–	7		—	
Coal	–	–	9		—	
Fireclay	–	2	6		—	
Coal	–	1	–	29	2	10
Blaes	–	–	2	29	3	–
Coal	–	1	6	29	4	6
Sandstone	3	1	4		—	
Coaly blaes	–	2	–		—	
Fireclay and balls	–	3	–		—	
Blaes and balls	–	1	7	34	–	5

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This last item is taken as the probable base of the Coal Measures and is followed in downward succession by a series of sandstones more than 18 fms. thick. On this view the total thickness of Productive Coal Measures present in this field is about 136 fms., although it no doubt varies somewhat for different parts.

The coal seams and their associated strata show considerable variation. Thus the Coalsnaughton Main is usually split into two or more leaves by hard 'stone' partings, though occasionally found as one seam with an average thickness of 3½ ft. The roof may be of sandstone or blaes, the pavement of sandstone, blaes or fireclay. The 'Mid-Cherry' Coal generally occurs as a single seam, while the 'Lower Splint' usually shows one or more partings. These names are purely local and not very satisfactory. There is diversity of opinion regarding the correct nomenclature and the same coal may pass under different names in adjoining fields. Correlation is rendered difficult by the absence of fossiliferous index-horizons, and by the fact that few bores have been put down of recent years, while many of the old boring records afford little help. The following group correlation with the Lanarkshire sequence is merely a tentative one :—

Lanarkshire.	Clackmannanshire.
(1) Upper Coals (down to Virtuewell).	(1) Down to Nine-foot Coal.
(2) Kiltongue-Drumgray Coals (K. Musselband to Lower Drumgray).	(2) Crowburn Ironstone to Coalsnaughton Main Coal.
(3) Armadale Coals (Mill to Crofthead).	(3) From "Mid Cherry" downwards.

Central Coalfield

In addition to the routine revision work carried on in other coalfields, every opportunity was taken to keep in touch with borings in progress in the Central coalfield. The total length of cores of which annotated records have been made and filed during the past year in this coalfield alone amounts to over 8,000 feet. Much economic and scientific information has thus been collected which would otherwise have been largely lost, and for permission to examine the borings our thanks are due to the various colliery companies concerned.

In most cases the records are confidential in the meantime, but through the courtesy of Mr. H. M. Cadell, of Grange, we are able to summarise the results of several borings made by him in the Bo'ness district. The first of these was put down at the old quarries at Burnfoot (Linlithgow, 1 N.E.), and started a short distance below the crop of No. 1 Carriden Limestone.

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The total depth was 76 fms. and the following are the more important items recorded :—

	Thickness. Fms.	ft.	in.	Depth from surface. Fms.	ft.	in.
Fakes and sandstone	6	5	4	6	5	4
Faky blaes	–	3	8	7	3	–
Blaes and balls; scattered shells	1	5	–	9	2	–
Limy fakes	–	–	3	9	2	3
Hard crinoidal LIMESTONE (No. 2 CARRIDEN)	–	2	10	9	5	1
Blaes and fireclay	–	4	8	10	3	9
Limestone rib	–	–	7	10	4	4
Ashy fakes	1	–	8	11	5	–
Ash, bedded; with occasional plant fragments (CARRIDEN ASH)	5	4	5	17	3	5
Blaes	–	–	3	17	3	8
COAL with a 1-in. rib	–	2	6	18	–	2
Blaes	1	4	5	19	4	7
Hard crinoidal LIMESTONE (No. 3 CARRIDEN)	–	1	4	19	5	11
Strata; chiefly fakes	3	0	1	23	–	–
Limy fakes	–	3	–	23	3	–
Shelly LIMESTONE (No. 4. CARRIDEN)	–	–	5	23	3	5
Shelly blaes	–	5	–	24	2	5
Fakes	–	–	4	24	2	9
COAL	–	–	8	24	3	5
Strata; mainly fakes; some thin ash beds and limy ribs	12	–	1	36	3	6
Blaes	1	–	10	37	4	4
Limy blaes	–	1	11	38	–	3
Sandy LIMESTONE	–	2	–	38	2	3
COAL	–	–	1	38	2	4
Fakes; some shell fragments at top	–	1	7	38	3	11
COAL	–	–	7	38	4	6
Strata; sandstone above, fakes below	8	5	11	47	4	5
Faky blaes; a few shells at 48½ fms.	5	–	4	52	4	9
Blaes with scattered shells and shelly ribs	5	5	5	58	4	2
LIMESTONE; crinoidal top; LITHOSTROTION band (No. 5)	1	5	2	60	3	4
Shelly blaes	1	–	3	61	3	7
Fakes and faky sandstone with some blaes	3	5	4	65	2	11
Pale coloured nodular rooty LIMESTONE; no fossils	–	1	6	65	4	5
Strata chiefly fakes and blaes	10	1	8	76	–	1
Total	76	–	1	—		

Another bore at Kinningars Park, almost ½ mile west of the preceding, proved the sequence from the Easter Main Coal down to No. 3 Carriden Limestone. Three marine horizons occur between the Easter Main and Smithy Coals, the lowest in the blaes above the latter seam. Immediately on top of the Smithy Coal occurs a dolerite sill, 16 fms. thick, recently described in detail by Mr. Cadell.[1] Its extremely vesicular top and bottom suggest intrusion under comparatively little cover. Thirteen

[1] *Trans. Inst. Min. Eng.*, vol. lix., 1920, p. 271.

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and a half fathoms below the Smithy Coal is the first of the Carriden Limestones, 22 inches thick; while No. 2 Carriden Limestone was met with 12⅔ fms. lower. From the blaes below the latter *Posidonomya corrugata* was obtained. The Carriden Ash is here represented by a few feet of ashy marl. From the blaes overlying No. 5 Limestone at Burnfoot has been obtained a fauna which suggests comparison with the Neilson Shell-bed overlying the Blackhall Limestone. On the same horizon lie the Fankerton Limestone of the R. Carron above Denny and the 'A' and 'B' Limestones of the Bannock Burn described by Mr. C. H. Dinham in the 'Summary of Progress for 1920' (pp. 35–38). Carriden No. 5 Limestone again is probably represented on the north side of the Forth by the thick Charlestown bed. Here two marine limestones, of which the lowest appears on stratigraphical and faunal grounds to be the equivalent of the Hurlet, are known to underlie the thick limestone. The Burnfoot bore did not go deep enough, it would seem, to prove these; but another boring, 400 feet east of Carras Gate, found a 2-foot crinoidal limestone overlying an 8-inch coal 9½ fms. below No. 5. There were clear signs of faulting between the two, and the lower bed perhaps represents the marine limestone occurring both at Charleston and in the Bannock Burn ('C' Limestone or Sandy Encrinital Limestone of Campsie) approximately midway between the Blackhall and Hurlet.

3. Borings for Oil at D'Arcy and West Calder

D'Arcy Oil Well.—In the Summary of Progress for 1920 an account of this boring was given to a depth of 150 fms. During 1921 the depth has been increased to 212 fms. From 150 to 175 fms. the beds consist of sandstones and shales with two thin seams of coal, probably only a few inches in thickness. At about 177 fms. there occurs a shale approaching to an oil-shale and which may represent one of the shales worked at Straiton, 6 miles to the west. Green and red mottled marls were drilled through between 181 fms. and 188 fms. below which the boring to a depth of 212 fms. continued in dark marly shales in which are three thin bands of limestone. Both the limestone and the shale contain entomostraca.

The boring was visited periodically and the samples examined by Mr. Tait, who from the type of sediments, especially the dark shales containing fish scales and entomostraca, considers that the boring is still proceeding in the Oil Shale Series.

West Calder Oil-Well.—Boring ceased on the 24th October 1921, at a depth of 3,923 ft., which is 17 ft. deeper than that given in the account in the Summary for 1920. The well proved unproductive and the hole is being filled.

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4. West Highland District

E. B. Bailey, M.C., B.A., District Geologist.
J. E. Richey, M.C., B.A.
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Moine Gneiss of Ardnamurchan

The work of the past season has shown that the metamorphic rocks of the western half of the Ardnamurchan peninsula are divisible into three major belts of which the western and eastern are psammitic in constitution, and the intervening one pelitic. The course of the pelitic belt runs roughly north and south from Carn Mòr, at the mouth of Loch Moidart, to Carna, in Loch Sunart. Its outcrop in general measures about a mile across, but, along the shores of Loch Sunart, folding leads to its having a breadth of 2½ miles. In the sequel, this gneiss will be spoken of as the Carna Pelitic.

Three main points of interest have been noted in regard to the psammitic rocks west of the Carna Pelitic :—

(1) Relict grains, or small pebbles of quartz and felspar, are recognisable throughout the whole belt. They become a conspicuous feature in certain particularly massive false-bedded gneisses, the outcrop of which extends, on the north coast, for two miles west from the Carna Pelitic, but southwards fails altogether in the upper reaches of Glenborrodale. Most of the rocks of the western psammitic belt may be described as flaggy rather than massive.

(2) Mr. Richey found a very low grade of metamorphism in the more westerly exposures of the belt at intervals along the coast between Ben Hiant and Kilchoan. The pre-Mesozoic foundation here consists, not of gneiss, but of well-bedded white felspathic grits, often pebbly and usually much sheared. East of Ben Hiant, more highly metamorphosed rocks are encountered characterised by pink felspar and obvious biotite. The Tertiary igneous rocks of Ben Hiant separate these two types as exposed along the shore section. The ground north of Ben Hiant, where their relations may perhaps be made out, has not yet been mapped.

(3) It has been found possible to map an approximate boundary for the massive gneiss mentioned under (1), even where it is in contact with the more widespread flaggy variety. Great assistance is afforded by the fact that the massive gneiss gives rise to some of the barest rock-scenery of the Highlands, whereas its flaggy associate disintegrates freely, and is for the most part covered by grass. On the north coast, Mr. Bailey finds the massive gneiss in contact on its eastern side with the Carna Pelitic. South of Lochan nam Fiann, Mr. Simpson finds flaggy gneiss inserting itself between the two; and in Glen Borrodale he has traced it sweeping round the termination of the massive gneiss to join with the main flaggy outcrop to north and west. It seems probable that the omission of the flaggy gneiss along the contact of the massive psammitic and pelitic belts, where these come together for three miles between the coast and Lochan nam Fiann, is due to a dislocation. At any rate there is a general discordance of strike of about 40° on the two sides of the boundary, and, though this becomes less marked at the actual contact (only exposed at two places according to Mr. Bailey), it remains

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clearly appreciable. The two contact exposures are of limited extent, but they show very little crushing, so that they suggest movement dating from the period of folding, rather than subsequent faulting. Some may prefer to claim the discordance as evidence of a stratigraphical unconformity, showing that the Carna Pelitic is of later date than its western neighbours.

The Carna Pelitic in much of its course, as, for instance, where it has been mapped by Mr. Simpson on the north shore of Loch Sunart opposite Carna, consists of three main divisions—an eastern and a western band of garnet-gneiss, and an intervening mixed assemblage of pelitic, semi-pelitic, and psammitic character, in which sandy calcareous seams are not infrequent. Near Loch Sunart the middle mixed division has a mean breadth of half a mile and it continues thus for 3½ miles northwards, and then thins away to nothing. For the next 3 miles it is unrecognisable, but north of Kentra Bay it puts in an appearance, and where it reaches the south channel of Loch Moidart, Mr. Eyles finds that its outcrop is almost half-a-mile broad.

The psammitic gneiss which lies east of the Carna Pelitic differs somewhat markedly from the western psammitic, in that it shows no recognisable pebbles of quartz and felspar. It is often very massive and bare of vegetation.

The difference of character of the two psammitic belts flanking the Carna Pelitic makes it rather difficult to account for the inconstancy of the middle division of the later as a result of folding.

TERTIARY IGNEOUS COMPLEX OF ARDNAMURCHAN

During the past season Mr. Richey has made progress in the investigation of two well-known centres of interest, the Ben Hiant vent and the Ardnamurchan gabbro.

In the following serial remarks, attention is restricted to that part of the Ben Hiant vent which lies in a general way east of the great intrusion forming the summit of the hill.

(1) The agglomerates so well exposed on the south and east sides of Ben Hiant include bands of fine-grained tuff. Where not horizontal, these bands are inclined into the hill, usually at low angles. Along the cliffs N.E. of Maclean's Nose individual bands are seen to continue for at least 100 yards.

(2) The junction between the agglomerate and the walls of the vent is on view in many sections. In the south portion of the hill the junction is vertical. On the east face and on an adjoining northern face it is inclined at angles of from 30° to 50° into the hill, *i.e.*, to west and south respectively; and tuff bands that here occur in the agglomerate are similarly inclined.

(3) A few sheets of inninmorite-pitchstone, up to 30 ft. in thickness, are associated with the agglomerates on the south side of the hill, into which they dip at low angles conformably to the bedding shown by the tuff bands in the agglomerates. Individual sheets consist of two portions :—

(*a*) A lower solid portion, with prismatic jointing forming upright hexagonal columns.

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(*b*) An upper amygdaloidal portion, with flat hexagonal columns of smaller diameter than the upright set of the lower portion.

A stream E. of Stallachan Dubha shows a sheet with the one set of columns curving round into the direction of the other. The base of this sheet rests on a fine-grained tuff which is baked for a depth of 2 ft. from the junction. The actual top of the sheet is not exposed.

Thin intrusive squirts of subvitreous pitchstone, evidently derived from the same magma, are a feature of the interior of these sheets. It is suggested that the pitchstone sheets are lava flows within the crater.

(4) A third of a mile S.E. of Ben Hiant summit, there is a line along which two prominent pitchstone sheets terminate abruptly. The margin of the vent takes a bend along the course of this line a little further downhill. Perhaps the line marks the course of a fault or the boundary of a secondary blow-hole that gave rise to a vertical wall against which later extruded pitchstone sheets abut.

(5) An area of porphyritic dolerite about ½ mile wide, occurs in the south portion of the vent between the outcrop of the two pitchstone sheets mentioned and Stallachan Dubha. The rock is characterised in the field by its spheroidal weathering. A steeply inclined clean-cut junction between it and agglomerate is exposed for 20 ft. in one of the stream gullies, just E. of the pitchstone sheets. The groundmass of the dolerite becomes somewhat vitreous within a few yards of the junction, but is not further chilled. The agglomerate appears to be unbaked.

(6) Abundant large blocks of basalt with conspicuous felspar phenocrysts characterise the agglomerates of the south portion of the vent. Some of the blocks are of enormous size. Nothing like them is met with farther north-east.

The great gabbro mass of Ardnamurchan Point is an intrusive complex which includes various types of gabbro as well as more acid rocks. The outer boundary of the complex has been traced from the northern side of the peninsula near Plocaig in an elliptical curve reaching the Sound of Mull, 3 miles S.S.E of the Point of Ardnamurchan. In addition, an isolated coastal exposure of a junction between gabbro and sediment has been found at the north end of Garbhlach Mhor. The complex area, about 7 miles long by 4 miles across, is disposed with the long axis bearing N. 60° E.

A small mass of acid rock, first recorded by Professor Busz,[1] lies between Achnaha and Glen Drian, and appears to mark a focus around which various more basic intrusions are disposed in a manner recalling the arrangement of the ring-dykes of Mull. The mass is situated a little to the N.E. of the centre; it has an elliptical outcrop with a major axis orientated in the same direction as that of the complex. The rock is allied to the tonalites and quartz-monzonites, and it becomes fine-grained towards its edge, where it sends numerous apophyses into the surrounding rocks, as may be seen in roadside exposures ¼ mile S.E. of Achnaha. The boundary lines of the various intrusions, surrounding the quartz-

[1] K. Busz in *Rep. Brit. Assoc.* for 1900, Bradford, p. 751.

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monzonite, so far as they have been investigated, follow a direction roughly parallel to the outer boundary of the whole complex. While the complex is free from the minor intrusions that so obscure the ring-dykes of Mull, its mapping is rendered difficult owing to the absence of screens of 'country-rock' which in Mull so often separate adjoining intrusions.

Progress has been made in the mapping of the country immediately outside the plutonic complex where minor intrusions (cone-sheets and sills) occur in enormous profusion. In numerous observed junctions of cone-sheets and sills, the former invariably cut and are chilled against the latter.

LEWISIAN COMPLEX OF COLL

One of the most debated points in Scottish geology for many years past has been the relations of the igneous and sedimentary portions of the Lewisian complex. Last season it was found that sediment enters largely into the eastern half of Coll. There are good coast sections, and it is possible to prove that the sedimentary gneisses here antedate the igneous, a relationship which Clough[1] considered probable both in the Loch Maree and the Glenelg districts of the North-west Highlands.

The north-east portion of Coll was mapped by Mr. Eyles, the central part by Mr. Bailey, and the south-west end by Mr. Simpson.

Igneous Gneisses.—The orthogneisses of Coll are for the most part intermediate or acid in composition, and granitic in texture. The prevalent type is a well-banded grey hornblende-biotite-gneiss, quartz-diorite in all but structure. Next to it in bulk is a comparatively unbanded pink acid rock, typical granite-gneiss.

A characteristic feature of the grey gneiss is the common occurrence within it of certain hornblendic layers, which, as several observers[2] in other regions have suggested, may be laminar inclusions of previously consolidated basic igneous rock. There are also some important outcrops of hornblende-schist associated with the sedimentary gneisses, and these are interpreted as intrusions.

Sedimentary.—The paragneisses of Coll consist mainly of magnesian marbles, quartz-granulites, and felspar-biotite-granulites. The mineral associations of the marbles and quartz-granulites are such as to leave no doubt that these rocks are metamorphic sediments. The felspar-biotite-granulites are more difficult to interpret. They are rather fine-textured rocks, consisting in large measure of granules of plagioclase associated

[1] C. T. Clough in 'The Geology of Glenelg' (*Mem. Geol. Surv.*), 1910, p. 19.

[2] *Cf.* C. E. Tilley, 'The Granitoid Gneisses of Southern Eyre Peninsula (South Australia) and their Associated Amphibolites,' *Quart. Journ. Geol. Soc.*, vol. lxxvii., 1921, pp. 81, 127.

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with evenly distributed, well orientated flakes of biotite; pink garnet in small crystals is a common accessory. The felspar-biotite-granulites are an easily recognisable type, largely on account of their fine texture, so that their distribution in Coll is thoroughly known. With trifling and easily understood exceptions, wherever felspar-biotite-granulite occurs, the more obvious sedimentary types (marble, quartz-granulite, or some type intermediate between these and felspar-biotite-granulite) are sure to be found also. This close association, coupled with the occurrence of intermediate types, and the frequent development of garnet (a very rare mineral otherwise in Coll) leads to the conclusion that the felspar-biotite-granulites are of sedimentary origin.

Quartz-granulites are best exposed at Ben Feall (east of Feall Bay), and impure marbles are also found on the eastern side of this headland. Rudha nan Uan (west of Hogh Bay) consists mainly of felspar-biotite-granulites. Another easily accessible exposure of marble is on the east shore of Loch Gorton

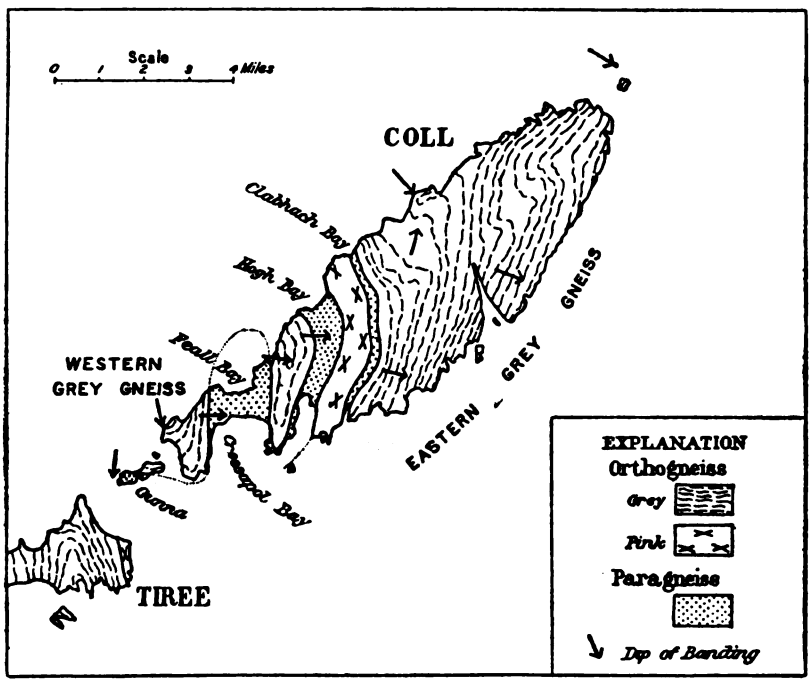

FIG. 4.—*Geological Map of the Island of Coll.*

at the south end of the Clabhach belt of sediment (*see* Fig. 4). A conspicuous feature of this Clabhach sedimentary belt is an outcrop of porcellanous quartz-rock, ranging from 15 ft. thick at Clabhach Bay to about 200 ft. thick where it crosses the road at Acha (3 miles farther south). Probably this quartz-rock is a metamorphosed sandstone, but possibly it is a quartz-vein.

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All the sedimentary types except the felspar-biotite-granulites are well-banded, and it is reasonable to interpret their banding as bedding. The cliffs of Ben Feall exhibit in imposing fashion the banding of the quartz-granulites, and it is certainly a more regular structure than the flow-banding of the orthogneisses.

DISTRIBUTION

The text-figure gives a good idea of the distribution of the ortho- and paragneisses of Coll. The grey banded type of orthogneiss has an important development north and east of the paragneisses or sediments. It can, in this outcrop, be properly described as overlying the sediments so far as observation reveals a relationship. West of this and actually within the sediments comes a great sheet of pink granite-gneiss some 2,500 feet thick, which runs south from Ben Hogh (east of Hogh Bay). Westwards, beyond the Hogh Bay outcrop of sediments, one meets once more with grey banded gneiss, which, however, almost certainly belongs to a mass or complex quite distinct from that of the eastern tract previously mentioned. The grey gneiss west of Hogh Bay is found on further enquiry to be contained in a fold which closes towards the south just as the south shore of the island is reached. Another similar southward closing fold of grey banded orthogneiss is met with west of Feall Bay.

The outcrops of dark hornblende-schist within or bordering the sedimentary belt, though of considerable breadth, are not large enough to be represented in the text-figure. A very good exposure occurs at the west end of Hogh Bay. There is also a minor outcrop of grey orthogneiss within the sediments, less than $\frac{1}{4}$ mile west of the Ben Hogh granite-gneiss. It has been traced for 2 miles, and is easily located on the ground where it gives rise to a gentle ridge known as Broadhills.

The sedimentary rocks have, with local exceptions, determined low-lying tracts in which superficial deposits such as blown sand and alluvium conceal much of the geology. Thus, while there are plenty of exposures to enable the accurate mapping of boundaries between ortho- and paragneisses, and while the coast sections afford good opportunities of studying marginal and other relationships, it has not been found possible to map out the various sedimentary types.

As a rough approximation it may be suggested that the sediments of the Clabhach belt are about 300 ft. thick and those of Hogh Bay about 2,500 ft.

Particular attention was given to the question of the relations of the sedimentary and igneous portions of the Coll complex. At various points decisive evidence was obtained that the igneous rocks are later than, and intrusive into, the sediments.

The most convincing exposure is half way up the west shore of Crossapol Bay ($\frac{3}{4}$ mile S. of Crossapol House), The sedimentary rocks here are felspar-biotite-granulites, often garnetiferous.

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Their main junction with the grey orthogneiss of the district runs out to sea just west of Port an Duine (a locality named on the 6-inch map, Argyll 50 S.W.). Just north-east of this the coastline takes a rather pronounced bend, and here, about 150 yds. within the boundary of the sediments, there occurs a band, some 20 yds. wide, of typical grey gneiss with layers and lenticles of hornblende-schist. It has been traced along the sea margin northwards for 400 yds. to its termination. This band envelops many thin layers and lenticles of the felspar-biotite-granulites. These are commonly three or four inches thick, but occasionally less. There does not seem any room for doubt that the grey orthogneiss has here invaded the granulite.

Another exposure occurs at the northern margin of the sandy shore of Hogh Bay. Sediment, represented by quartzose biotite-granulite, is here seen within a few feet of normal Ben Hogh granite-gneiss. Between, there is a grey igneous gneiss of variable nature which seems to interdigitate with, and at places merge into, its two neighbours. It is sometimes strikingly xenolithic with lumps rich in green hornblende. A few of the xenoliths are pale, and one such on slicing was found to consist of malacolite, basic felspar, calcite, and green hornblende. There can be little doubt that these xenoliths represent impure marbles derived from some portion of the sedimentary belt. Every stage of absorption can be traced with the ultimate production of hornblendic gneiss of peculiar type.

Following the top of the cliffs northwards for some 500 yds., one enters a belt of the Hogh granite-gneiss where xenoliths of felspar-biotite-granulite are widely distributed. Here again it seems fairly certain that the Hogh granite-gneiss is including fragments of one of the characteristic types of Coll sediments.

The Hogh Bay phenomena of xenoliths and contamination are re-exposed where the western margin of the Hogh Bay granite-gneiss skirts the eastern shore of Loch Breachacha. A slide from the narrow contaminated zone shows a typical norite-gneiss, and so recalls observations made by Lacroix[1] in contact-zones of the Pyrenees.

These details show that the igneous rocks of the Coll complex are intrusive into the sediments. Probably this accounts for the striking concordance of the two sets of rocks at every contact. Certainly it affords a very simple solution for the unique character of the Ben Hogh granite-gneiss—a feature which would be hard to explain on any hypothesis which interpreted the Ben Hogh belt as an infold of a general floor of pre-sedimentary orthogneiss.

Flinty Crushes.—A point of considerable interest is the frequency of flinty crush-rock in some parts of Coll. Examples have been found more particularly along the northern half of the east coast.

[1] A. Lacroix, 'Le Granite des Pyrénées et ses Phénomènes de Contact,' *Bull. des Services de la Carte géologique de la France*, Tome x., 1898–99, p. 263.

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CAMPTONITE DYKES

Messrs. Bailey, Eyles and Simpson record camptonites among the late dyke-rocks of Coll and Tiree, and also from Ardnamurchan east of Hacarsaid. In ten out of eleven coastal exposures of camptonite dykes in Coll, the direction is N.W. or W.N.W. In 15 out of 25 coastal exposures in Ardnamurchan the direction lies roughly between N.N.W. and W.N.W. In three cases camptonites are seen cut by basalt dykes of normal Tertiary appearance, a relation in conformity with a rule which Dr. Clough and others have found to hold in the West Highlands generally. Owing to the absence of camptonite dykes in the gneiss areas of Western Ardnamurchan, no opportunity is afforded there of testing the age of these dykes against the Mesozoic sediments or Tertiary lavas.

PRE-GLACIAL MARINE EROSION

Mr. Richey reports a hitherto undescribed occurrence of a shore-line in Ardnamurchan apparently corresponding with Mr. Wright's[1] pre-Glacial coast of western Mull, the Treshnish Isles and Colonsay.

It is marked by a level rock-notch on the hill slopes above Kilchoan Bay, where for a mile it is a conspicuous feature of the landscape. At its north-east end it was found to stand 145 ft. above O.D. This is some 20 ft. higher than on the west coast of Mull, but the pre-Glacial sea-cave of Ulva, described by Mr. Burnett in last year's Summary of Progress (p. 42), has a floor at 150 ft. above high-water mark (roughly speaking, 155 ft. above O.D.).

The pre-Glacial age of this high-level Kilchoan notch seems to follow with probability from the following facts :—

(1) No gravels are preserved in connection with the notch. The highest gravels are those of the late-Glacial 100-foot beach exposed, for instance, at the Free Church Manse.

(2) The platform of the notch has suffered a modelling by erosion, which does not seem to have affected the late-Glacial and post-Glacial beach-gravels, occurring as well preserved flats at lower levels.

Ice Flow.—Numerous striæ show that the Ardnamurchan peninsula has been crossed obliquely by ice, moving in a general west-north-west direction. In Coll, evidence is much more difficult to obtain, but Messrs. Bailey and Eyles noted a few striæ at various points in the north-east half of the island which are also directed approximately W.N.W. Their observations here agree with those of Professor James Geikie.

As might be expected, blocks of the great Morven granite are to be met with at intervals in all parts of Ardnamurchan. In Coll, erratics are curiously few, so that it is worth drawing attention to a conspicuous black boulder, 8 × 7 × 4 ft. mounted 200 ft. above sea-level on the pale rocky slopes of Ben

[1] W. B. Wright, 'Pre-glacial Shoreline in the Western Isles of Scotland,' *Geol. Mag.*, 1911, p. 97.

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Hogh, 300 yds. north-west of the head of Loch nan Cinneachan. The boulder consists of olivine-gabbro of Tertiary type.

ECONOMICS

The Raasay Ironstone is exposed in the shore section westwards of Kilchoan at the following localities situated one mile apart :—

(1) Below high water mark, ⅝ mile S.W. of landing jetty, Port Mor, Kilchoan, and 700 yds. E. 10 N. of trigonometrical station on Maol Buidhe.

(2) Below high-water mark, 970 yds.W. 8° N. of trigonometrical station on Maol Buidhe. Owing to the sea-cliffs this place is somewhat difficult of access. It may be reached when the tide is out, along the shore from the east, or by a steep path down the cliff, which gains the shore a little east of the exposure.

At locality (1) the Upper Lias shales are riddled by basic sheets and sills, and so occur in disconnected areas of small extent. In one of these, Dr. G. W. Lee was led to an outcrop of the Raasay Ironstone by the occurrence in the underlying shales of the *Harpoceras-Dactylioceras* fauna typical of the horizon in Raasay. The ironstone appears unaltered by the igneous intrusions. It is limy and oolitic with shaly layers, and contains belemnites. Its top is not exposed, and the total thickness seen is about 2 feet.

At locality (2) the strata are fairly free of minor intrusions, but are highly baked by the neighbouring gabbro mass. The Upper Lias shales were recognised here by Mr. Richey from their position between strata taken to represent the Middle Lias and Inferior Oolite respectively. The ironstone is altered to magnetite, but belemnites can be recognised in it. The seam is fairly solid with shaly layers. It is fully exposed and is 4 ft. thick.

On Ardnamurchan, owing to the profusion of igneous intrusions, there is absolutely no prospect of the Raasay Ironstone proving of economic value (*see* p. 109). It may occur below the Tertiary lavas in the extreme north of Mull. If a search by boring were ever contemplated there, the locality suggested is the promontory between the Ardmore and Bloody bays, which is about 3 miles south of the Ardnamurchan outcrops. There, on the west side of Bloody Bay, about 1¼ miles S.E. of Ardmore farm, a massive red sandstone[1] immediately underlies the lavas. Its age is unknown, but it is at any rate later than the Lias.

It may be mentioned that a reddish sandstone of Inferior Oolite age occurs on the opposite Ardnamurchan shore, east of Sron Bheag point, and this may perhaps be the position of the sandstone of Bloody Bay.

Mr. Ennos has completed the estimation of iron in the magnetic ore referred to in the " Summary of Progress " for 1920 (p. 43),

[1] ' Summary of Progress ' for 1920 (*Mem. Geol. Surv.*), 1921, p. 37.

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as occurring in two localities near the southern end of Iona. He finds in each case between 29 and 30 per cent. of metallic iron, corresponding to about 40 per cent. of magnetite. The degree of concentration is thus not great enough to make the deposits likely to be of value.

5. North Highland District

M. Macgregor, M.A., B.Sc., District Geologist.
G. V. Wilson, B.Sc.
H. H. Read, M.Sc., A.R.C.Sc.
D. Haldane, B.Sc.
G. Ross, B.Sc.
} Geologists.

Field-work was carried on during the summer months in the northern and central parts of one-inch Sheet 102 west of Loch Shin and along the Oykell and Lower Cassley valleys. The survey was extended westwards as far as Oykell Bridge, and the only part of the Sheet not yet examined is an area of about 30 square miles along the south-western margin between Lubcroy and Corriemulzie. The ground reported on below lies partly in Ross-shire, partly in Sutherland.

Ross-shire

On the south side of the river Oykell (the county boundary) the area mapped by Messrs. Read, Haldane and Ross stretches from the lower part of the Einig eastwards to Wester Rhelonie, and extends southwards to the Oykell–Carron watershed. Mr. Ross finds that the rocks in the western part of this strip are almost entirely siliceous schists varying in type from massive and rather coarse-grained quartzo-felspathic gneisses to more flaggy schists rich in muscovite. The former type is well-exposed in the gorge of the Oykell to the west of Torr a' Chorcain and along the belt of shattered rock which crosses Beinn Chreagach. Good sections of the more flaggy type occur in the Allt Mòr and its tributaries, where the dip is uniformly S.W. at angles of 25 to 50 degrees; and in the Einig, where the flags are somewhat thicker (6 to 10 in.) and the dip varies from S.S.E. to S. at angles of 25 to 40 degrees. Bands of a semi-pelitic facies are rare but occur at one or two localities, *e.g.*, to the east of Lochan Phail on the north bank of the Allt Mòr.

The shattered rocks on the north-west edge of the Beinn Chreagach ridge give rise to a conspicuous line of scree slopes extending south-westwards from Creag Langwell. A similar but much more marked shatter-belt extends from Creag Langwell westwards across the upper streams of the Alltan Beaga and along the steep southern bank of the Oykell south of Loch Thurnaig, and then, turning south-east, crosses the Einig about 500 yds. N. of the mouth of the Allt nan Caisean. The same crush-line is well-exposed east of Langwell in the burn at

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Brae, where Mr. Read finds the granulites to be contorted and brecciated with much iron staining in the crush-jaws. East of this locality, however, it cannot be followed, for at Doune and at Innis nan Damh the undisturbed and regularly dipping flags occur right across its line. The country rock here consists of the usual pale-coloured siliceous granulites showing here and there pebbles of pink felspar (*cf.* p. 100). The dip is usually high and varies in direction from S. towards S.S.E. or S.S.W. Good sections can be seen in the burns to the west of Brae and around Loch Mhic Mharsaill. Farther south towards the Oykell–Carron watershed, on the slopes of Beinn Ulbhaidh the siliceous granulites are evenly interbedded with subordinate semi-pelitic bands. These latter, each an inch or two in thickness, owe their darker colour to the presence of abundant flakes of black mica.

Higher up on Beinn Ulbhaidh the semi-pelitic bands increase in bulk and their biotite-content becomes greater; if the ground were not so much obscured by peat it might be possible to trace a transition from the siliceous granulites into the thoroughly pelitic schist of Beinn Ulbhaidh. This pelitic schist occurs on the summit of the hill and is exposed also in the headwaters of the Allt Mòr which rise on its slopes. It is a dark-coloured, lustrous and thoroughly micaceous schist, studded with small pink garnets of the size of peas. It extends from the top of Beinn Ulbhaidh eastwards for perhaps·2 miles, while its breadth across the strike is less than a mile. On all sides the pelitic rock appears to be surrounded by the siliceous and semi-pelitic type already referred to, and is not visibly connected with the belts of pelitic schist known to occur farther to the south-west on the high ground around Carn a' Choin Deirg.

Mr. Haldane reports that the ground examined by him east and south-east of Inveroykel is largely drift-covered. Good sections are seen, however, in the numerous streams flowing N.E. and N. to the river Oykell, here tidal and called the Kyle of Sutherland. The country rock is predominantly a pale-coloured flaggy siliceous granulite, showing marked colour-banding in places. Here again the biotite-content may show a notable increase until the rock passes into a semi-pelitic type. Such semi-pelitic bands with an east to west trend occur on the east shoulder of the Coire's Airde ridge in the upper part of the Kilmachalmack Burn and on the north face of the summit of Breac Bheinn. In the south-west of the area the semi-pelitic character becomes more pronounced as the mica-schist of Beinn Ulbhaidh is approached. There is a marked absence in this ground of the granite and pegmatite veining, which is so characteristic of the country N.E. of Invershin.[1]

Well-marked mullion-structure is seen at several localities, especially in the western part of the area. The general direction of rodding is towards the south-east, parallel to the pitch of the

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, p. 45.

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folds. Fine examples of this structure are found in the Oykell at Oykell Bridge.

Igneous Rocks.—Mr. Ross reports the occurrence of two lamprophyre dykes, possibly branches of one main east-and-west intrusion, in the Allt Mòr about 300 yds. above the mouth of the Allt Fliuch Bhadain. The northern one, about a foot thick, is brick-red in colour and shows large plates of biotite. It is inclined N. 10° E. at 60 degrees. The other dyke, 100 yds. south, is parallel to the first and very similar, but contains many inclusions of schist showing rounded corners and varying in diameter from 3 to 6 inches. These inclusions are well seen on the polished dip face of the dyke, which forms the southern bank of the stream for about 30 yds. A similar lamprophyre crosses the river Einig a few yards upstream from the mouth of the Alltan Beithe, but no inclusions of schist were noted. These dykes no doubt belong to the same series of intrusions as the lamprophyres described in the 'Summary of Progress' for 1920 (p. 47), from the Invershin and Bonar Bridge district.

At Creag a' Chait, the prominent hill south-west of Achnagart, Mr. Haldane has mapped a basic rock, showing traces of shearing in places, which extends 350 yards in an east-and-west direction, and is about 30 yds. wide.

At the top of the hillside at the top of the road and about 1,000 yds. south from Creag a' Chait there are a small knob and some scattered boulders of a basic mass similar to some of the hybrid rock types found at Ach'uaine and Ledsaurich[1], 5 miles to the east.

SUTHERLAND

On the north side of the river Oykell Messrs. Macgregor, Read and Ross have mapped the ground around Altass, lower Glen Cassley, Beinn Rosail and Carn Mòr. In the western part of the area excellent sections are provided by the Allt an Leacach, the Allt Bad Air Donnadh and the Tutim Burn. The dominant rock types here are rather massive flaggy siliceous schists, frequently somewhat coarse in texture, with pebbles of pinkish felspar; in some cases these pebbles are as much as a quarter of an inch in diameter and show granulitised edges. Bands of quartzite with scattered felspar crystals occur among the flags, but rocks of a semi-pelitic or pelitic facies are conspicuously absent over most of the ground. The thin micaceous partings which locally separate the flags become thicker and more abundant however in the neighbourhood of Loch na Claise Moire and near the summit of Carn Mòr. The dip is very uniform in direction, varying slightly around S. 40° W. at angles of 30 to 70 degrees. On the higher ground, around Beinn Rosail and on Carn Mòr, the rocks are often much puckered and folded. Colour-banding is common, the darker tints being produced by varying amounts of biotite in small flakes. In Glen Cassley

[1] *Ibid.*, pp. 46–47.

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Mr. Ross finds the same rock types developed, but the pebbly character is less marked, and the flags are finely and evenly grained granulites of normal aspect. They are traversed on the east side of the glen by several crush-belts marked by breccias cemented by vein quartz. The general direction of the crush-lines is N.N.W.–S.S.E., parallel with the glen. Dips are high and mainly towards the W.S.W., but in the lower part of the Cassley valley the strike swings round into an east-and-west direction. Farthest east around Altass again the general strike is N.E.–S.W., and here Mr. Read notes that the dominant rock type is supplied by very finely flaggy beds. These are well-exposed in the Allt Mòr, a strike stream developed along a belt of fine-grained quartz-felspar-granulites separated into flags by the abundant development of large scales of white mica in parallel planes. These planes are less than an inch apart and from their regularity and extent are the cause of the remarkable topography of the Allt Mòr. The gorge of this burn is, on its south-east side(*e.g.*, the side towards the dip), defined by a vertical wall of rock, while its north-west side is an inclined *glacis* of flag planes.

On the high ground east of Glen Cassley, towards the water-shed between the Cassley and Grudie rivers, Messrs. Read and Ross find that the dominant rock type is a granulite with numerous biotite-rich bands. These striped rocks appear to occupy an area extending from Loch Doire a' Chatha N.N.E. along the strike to the neighbourhood of Carn na Ba' Maoile. The mica-rich bands are exceedingly narrow and often twelve or more of them alternate with pale quartzo-felspathic ribs in the space of an inch.

Mr. Wilson completed the mapping of the ground on the west side of Loch Shin from Salachy northwards to the boundary of one-inch sheet 102. This tract is largely covered with peat or drift and exposures of rock are few. The country-rock consists of flaggy siliceous granulites. Occasionally more massive beds composed of felspathic grits occur, and these in many instances seem to have undergone little metamorphism.

Igneous Rocks.—Messrs. Read and Ross report the occurrence of hornblendic rocks at two localities—at the waterfalls in lower Glen Cassley and in the Allt Doire a' Chatha, near the croft of Doire a' Chatha (Durcha). The rocks are essentially similar at both places. Among the different types that occur is a coarse dark-green or black rock composed almost entirely of hornblende, the acicular crystals of which show a tendency to lie with their vertical axes in one plane. In the Cassley section the rocks of this type seem to be definitely intrusive into the granulites, and at the upper falls one of these intrusions has been broken up into lenses by later movements. A slightly different type is one where the hornblendic material is banded with narrow threads of a pale-coloured felspathic substance; and by an increase in the number of such bands the rock takes on a markedly striped aspect.

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The striping is extremely delicate and persistent; it runs parallel with the foliation of the neighbouring granulite. The hornblendic layers of these striped rocks contain some greenish mica in addition and, occasionally, chlorite. Often also on the plane surfaces of the "stripes" throughout both the felspathic and hornblendic portions there are large bladed crystals of green actinolite up to 2 inches in length which lie with their vertical axes in the foliation planes but show no other orientation. A final type is represented by a rock mainly felspathic in character but with very regular, delicate and persistent bands of hornblende often less than one-twelfth of an inch in thickness. On the whole these hornblendic rocks seem to be of igneous origin; the delicate banding may be due to their heterogeneous intrusion early in the period during which the granulites received their present structure. Somewhat later the original ferro-magnesian minerals of the striped rocks were probably converted into the stress-mineral hornblende and large blades of actinolite formed upon the foliation planes.

These rocks resemble the hornblendic schists associated with the well-known Shiness Limestone.

On the south side of the River Grudie at Meall a' Ghruididh and Cnoc na Cloich-bhuaile, 3 miles W.S.W. from Lairg, Mr. Read has mapped a small mass of granite a little over a square mile in extent. It is an unfoliated coarse pink rock often showing abundant drusy cavities. The components are porphyritic pink orthoclase felspar up to half an inch in length, rounded blebs which occasionally show crystal outlines, and a few small biotite plates.

An exposure of a dark-blue, ultrabasic rock allied to scyelite was noted by Mr. Ross in a small stream flowing east into the Cassley below Glencassley Castle.

On the north-east side of Loch Shin, west of Sithean Dubh Mòr, Mr. Wilson has mapped a few small bosses of scyelitic rock similar to those previously noted by Mr. C. H. Dinham in the same district.

At two localities in Mr. Wilson's ground—Arscaig in the north, and Salachy in the south—belts of hornblende-schist occur. In both cases the rock varies in composition from nearly pure hornblende to a banded material consisting of finely striped siliceous and hornblendic layers. A search was made for the re-appearance of the Shiness Limestone at Arscaig, but without success. At the quarries at the east side of the Loch the limestone is associated with striped hornblendic rocks similar to the above, but at Arscaig the latter alone are present. Certain bands rich in epidote in the granulites may possibly represent originally calcareous layers.

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III.—PETROGRAPHICAL WORK

1. England and Wales

Petrographical work in connection with England and Wales has been carried out by Dr. Thomas chiefly in answer to enquiries from private individuals and Government departments.

An interesting post-Triassic dyke mapped by Mr. Pocock during the survey of Sheet 138, forms the subject of an appendix (p. 154).

A few rocks from Signey I. in the South Orkney Is., collected by Mr. H. E. Borge of the Tonsberg Whaling Co., and submitted for examination by the Under Secretary of State for the Colonies, are of considerable interest as they indicate the existence in that region of more ancient and more highly metamorphosed rocks than those previously collected and described from Coronation I., Laurie I., and Weddell I. The earlier collections from the South Orkneys were of relatively unaltered sedimentary rocks of presumably palæozoic age, but the specimens from Signey I. are mica-schists, foliated quartzites and metamorphic limestones. The mica-schists are dark grey well-foliated quartzose rocks composed of quartz, biotite and muscovite with porphyroblastic pink garnet. The white crystalline limestones are foliated and consist almost entirely of calcite enveloping minute well-formed crystals of diopside and less frequent actinolitic hornblende.

An investigation has been carried out for the Government Laboratory on the crystalline and optical properties of members of a series of artificial compounds that are connected with the manufacture of certain explosives.

2. Scotland

Petrographical work in connection with the forthcoming memoir on the Island of Mull (Sheet 44) has occupied the greater part of Dr. Thomas' attention during the past year. His descriptions of the rocks collected from Sheet 54 (Moor of Rannoch) have been handed to Mr. Read, who has been entrusted with the task of writing with their aid the petrographical sections of the memoir on this region.

Connected with the current Survey work Dr. Thomas has reviewed and described new material from Mull and from the islands of Iona, Tiree, etc., as well as from Ayrshire, Renfrewshire and other southern counties. The current work on Sheet 102 (Bonar Bridge) is being carried out by Mr. Read.

From Iona, Mr. Anderson has submitted for examination a suite of pelitic schists and gneisses and the associated tremolite- and forsterite-marbles known respectively as Iona marble and Silverstone. He has also collected a beautiful hornblende-eclogite composed of green hornblende, omphacite, idiomorphic pink garnets, well-formed prisms of pleochroic hypersthene, plagioclase felspar, a little fox-red biotite and quartz.

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The foliated gneisses of the Lewisian Complex of the island are mainly plagioclase-gneisses and are characteristically rich in epidote. Amongst them is a curious magnetite-bearing rock, composed almost entirely of magnetite, fibrous hornblende and garnet, which is associated with interesting types consisting of pink garnet and chlorite, and garnet and quartz.

The supposed Torridonian sediments that come within the influence of the westerly extension of the Ross of Mull granite have the characters of biotite-hornfelses and occasionally carry andalusite.

The ancient rocks are cut by a series of irregular unfoliated intrusive sheets of porphyrite, amongst which quartz-mica-porphyrites, hornblende-porphyrites and albite-porphyrites are represented.

Some of the later dykes of Iona show their similarity to others described from the Ross of Mull and the neighbouring Colonsay by their monchiquitic and lamprophyric affinities—good monchiquites and camptonites are well represented.

As a result of his work on the Lewisian Gneiss of the outlying island of Tiree, Mr. Bailey has submitted a suite of specimens (20828–20839) to illustrate the sediments, and certain closely associated rocks, of the Dun Gott exposure. The main type is a pyroxenic gneiss; but a forsterite-marble (20837), a graphite-schist (20838). and a garnet-biotite-gneiss (20834) are characteristically represented. An interesting thin seam from near the margin of the outcrop is a beautiful eclogite (20828) similar to that from Iona mentioned above. It is composed of omphacite, hypersthene, garnet, and quartz—and parts of the slide are relatively rich in pyroxene or quartz, as the case may be, and poor in garnet.

The orthogneisses of Tiree collected by Mr. Bailey include basic hornblende-schists, intermediate hornblende-biotite-gneiss, and acid quartzo-felspathic gneisses.

A quartzose orthophyre-sheet collected on the shore east of An Cnap (20845) likely belongs to the Old Red Sandstone period. Otherwise the late minor intrusions sliced vary from basalt to camptonite in composition. Good camptonites have been met with as north-west dykes, one west of Librig Mhor (20852) and another south of Poll a' Chrosain (20853). A somewhat decomposed sheet from a little island north-north-west of Miodar (20842) is also of somewhat camptonitic type. It has porphyritic crystals of pale violet augite and pseudomorphs after olivine, together with small columnar crystals of augite, cloudy oligoclase, and some brown hornblende in an alkali-felspar base; a high power shows abundant needles of apatite.

From Sheet 22 (Ayrshire), in addition to a large collection of basalts and andesites of Old Red Sandstone and Calciferous Sandstone ages, an interesting teschenitic rock has been examined from the Hillhouse Quarry. This rock varies considerably in

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texture, the coarser portions containing abundant ophitic titaniferous augite, while the finer portions are much more alkaline in character. The finer portion, which often acts as matrix to the coarser textured rock, is composed of titaniferous augite edged with ægirine, blade-like crystals of ægirine and rich yellow-brown biotite, in a base of analcite crowded with needles of apatite.

A good suite of trachytic lavas of Calciferous Sandstone age has been collected by Mr. Burnett from the neighbourhood of Moorhouse, Bannerbank, and Mid Floak in Renfrewshire. Many are typical trachytes, but others are best described as trachybasalts or trachydolerites.

IV.—CHEMICAL WORK

During the past year analyses were made of 24 igneous rocks, two of these being from Mull (for Memoir on Sheets 43, 44), and the rest from Aberdeen and Banffshire (for Memoir on Sheets 86, 87 and 96). In addition four Scotch iron ores were analysed. The results of the analyses are appended below.

For completing the work on Fireclays for the Special Report on British Refractory Materials a further eighteen analyses have been made.

The chemical and mineralogical composition of the Strathmore Meteorite has also been determined.

The following are rocks analysed for Memoir on Sheets 86, 87 and 96 :—

20322. Lab. No. 642.
Olivine-norite. Knob in front garden of New Forest, Kirkney Water, Aberdeenshire. 1 in. sheet 86. 6 in. Aberdeen 42 N.E.

20324. Lab. No. 644.
Granite. Quarry, ¼ mile S. & E. of Weets, Insch, Aberdeenshire. 1 in. sheet 86. 6 in. Aberdeen 34 S.E.

20327. Lab. No. 645.
Hypersthene-gabbro. Escarpment, ½ mile W. of Bridgend of Shevock, Insch, Aberdeenshire. 1 in. sheet 86. 6 in. Aberdeen 44 N.E.

20328. Lab. No. 646.
Olivine-gabbro. Old Rand Pit, Bonnyton, Insch, Aberdeenshire. 1 in. sheet 86. 6 in. Aberdeen 35 S.E.

19969. Lab. No. 663.
Contaminated gabbro at edge of Insch Igneous Mass. 400 yards S. by E. of Easter Saphook, Old Meldrum. 1 in. sheet 86. 6 in. Aberdeen 45 N.E.

19906. Lab. No. 660.
Quartz-diorite of the Insch Mass. Graveyard Railway Cutting. 430 yards S.S.E. of Leith Hall, Kennethmont. 1 in. sheet 86. 6 in. Aberdeen 43 N.W.

20326. Lab. No. 661.
Quartz-dolerite. Dyke in olivine-norite, Auchinbradie Quarry, Knockenbaird, Insch. 1 in. sheet 86. 6 in. Aberdeen 44 N.W.

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19654. Lab. No. 662.
Norite of Huntly Igneous Mass, Hill of Mungo, 3 miles N.N.E. of Huntly. 200 yds. W. by N. of Summit, at wall. 1 in. sheet 86. 6 in. Aberdeen 26 N.E.

20487. Lab. No. 664.
Diorite of Huntly Igneous Mass. Knob in field on S.W. side of Craigwillie, 1 mile W. of Huntly. 1 in. sheet 86. 6 in. Aberdeen 26 S.W.

20488. Lab. No. 665.
Uncontaminated Norite of Arnage Mass. Railway cutting, 600 yds. S. of Mill of Inkhorn, Arnage, Ellon. 1 in. sheet 87. 6 in. Aberdeen 30 S.E.

20489. Lab. No. 666.
Contaminated Norite of Arnage Mass. Quarry at roadside, ½ mile N.E. of Mains of Drumwhindle Arnage, Ellon. 1 in. sheet 87. 6 in. Aberdeen 38 N.W.

20490. Lab. No. 667.
Much contaminated Norite of Arnage Mass, Carding Hill, 700 yards S.S.E. of Arnage House, Arnage, Ellon. 1 in. sheet 87. 6 in. Aberdeen 30 S.E.

20583. Lab. No. 674.
Cullen Quartzite. Shore, S.W. side of Craig Head, midway between Findochty and Portessie, Banffshire. 1 in. sheet 96. 6 in. Banff. 2 N.W.

20584. Lab. No. 675.
Micaceous bands in Cullen Quartzite. In little port on landward side of Bow Fiddle, N.E. side of Portknockie, Banffshire. 1 in. sheet 96. 6 in. Banff. 2 N.E.

20585. Lab. No. 676.
Typical Findlater Flag. Findlater Castle, 2 m. E. of Cullen, Banffshire. 1 in. sheet 96. 6 in. Banff. 3 N.W.

20586. Lab. No. 677.
Actinolite-schist. West side of Garron Point, ½ m. N.N.W. of Sandend, Banffshire. 1 in. sheet 96. 6 in. Banff. 3 N.E.

20587. Lab. No. 678.
Black Schist from Sandend Group. N. side of Sandend Harbour, Banffshire. 1 in. sheet 96. 6 in. Banff. 3 N.E.

20588. Lab. No. 679.
Durn Hill Quartzite. Durn Hill Quarry, 1 mile S.S.W. of Portsoy, Banffshire. 1 in. sheet 96. 6 in. Banff. 3 S.E

20589. Lab. No. 680.
Graphite-schist, from Portsoy Group Hythe of John Legg's Well, west side of Portsoy, Banffshire. 1 in. sheet 96. 6 in. Banff. 3 N.E.

20590. Lab. No. 681.
Cowhythe Gneiss. Strathmarchin Bay, east side of East Head, Portsoy, Banffshire. 1 in. sheet 96. 6 in. Banff. 4 N.W.

20591. Lab. No. 682
Andalusite-schist. Shore, ½ mile, E. of U.F. Manse, Whitehills, Banffshire. 1 in. sheet 96. 6 in. Banff. 4 S.E.

20592. Lab. No. 683.
Macduff Slate. At cave in Old Haven, at mouth of Burn of Melrose, 2 miles E. of Macduff, Banffshire. 1 in. sheet 86. 6 in. Banff. 5 S.W.

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Slice No.	20322	20324	20327	20328
Lab. No.	642	644	645	646
SiO_2	45·32	77·36	49·30	44·65
TiO_2	6·03	·18	3·19	3·69
Al_2O_3	14·25	10·01	14·03	17·95
Fe_2O_3	1·74	·84	·09	1·09
Cr_2O_3	nt. fd.	nt. fd.	nt. fd.	nt. fd.
V_2O_3	nt. fd.	nt. fd.	nt. fd.	nt. fd.
FeO	14·82	·56	9·61	15·02
MnO	·11	·12	·31	·36
(CoNi)O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
BaO	·03	·04	nt. fd.	·01
CaO	8·80	·72	12·31	9·50
MgO	3·72	·09	6·82	3·34
K_2O	·83	5·10	·30	·54
Na_2O	2·59	3·28	2·66	2·79
Li_2O	nt. fd.	nt. fd.	trace	trace
H_2O at 105° C.	·10	·08	·11	·10
H_2O above 105°C.	·37	·26	·76	·45
P_2O_5	·74	·98	·05	·09
FeS_2	·09	nt. fd.	·08	·12
Fe_7S_8	·37	nt. fd.	nt. fd.	·12
CO_2	·31	·44	·42	·28
Total	100·22	100·06	100·04	100·10

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Slice No.	19969	19906	20326	19654	20487	20488	20489	20490	Slice No.
Lab. No.	663	660	661	662	664	665	666	667	Lab. No.
SiO_2	56·18	56·07	50·78	49·18	51·57	52·04	62·39	47·88	SiO_2
TiO_2	1·54	2·38	4·65	1·24	3·83	·66	·99	1·49	TiO_2
Al_2O_3	19·17	13·18	9·64	16·00	16·15	16·31	17·33	26·35	Al_2O_3
Fe_2O_3	·47	1·22	3·27	·02	·37	·06	·48	·95	Fe_2O_3
Cr_2O_3	nt.fd.	nt.fd.	nt.fd.	·03	nt.fd.	·05	nt.fd.	nt.fd.	Cr_2O_3
V_2O_3	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	·01	nt.fd.	nt.fd.	V_2O_3
FeO	9·84	7·47	10·72	8·02	10·39	7·98	7·19	12·01	FeO
MnO	·15	·26	·26	·20	·14	·14	·18	·18	MnO
(CoNi)O	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	(CoNi)O
BaO	·09	·14	·01	trace	·02	trace	·03	·01	BaO
CaO	2·16	7·01	9·62	12·54	6·94	7·24	2·10	2·91	CaO
MgO	2·97	4·87	5·12	9·47	4·96	11·70	2·81	2·87	MgO
K_2O	2·61	2·44	·70	·26	·93	·89	·48	1·31	K_2O
Na_2O	1·71	2·79	2·31	2·04	2·69	1·82	3·41	1·75	Na_2O
Li_2O	trace	trace	nt.fd.	trace	trace	trace	nt.fd.	trace	Li_2O
H_2O at 105° C.	·28	·12	·77	·07	·08	·06	·11	·23	H_2O at 105° C.
H_2O above 105° C.	1·85	·90	·86	·41	·61	·51	1·47	1·32	H_2O above 105° C.
P_2O_5	·09	·23	·21	·10	·46	·08	·22	·32	P_2O_5
FeS_2	·28	·14	·02	·02	·06	·02	·05	·23	FeS_2
Fe_7S_8	·49	·22	·31	·37	·50	·51	·58	·16	Fe_7S_8
CO_2	·15	·63	·80	·33	·48	·46	·42	·23	CO_2
Total	100·03	100·07	100·05	100·30	100·18	100·54	100·24	100·20	Total.

Anal. E. G. RADLEY.

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Slice No.	20583	20584	20585	20586	20587	20588	20589	20590	20591	20592	Slice No.
Lab. No.	674	675	676	677	678	679	680	681	682	683	Lab. No.
SiO_2	86·12	60·70	66·33	54·44	60·95	96·58	44·83	67·23	53·98	58·47	SiO_2
TiO_2	·39	1·32	·99	1·05	1·17	trace	1·05	·86	1·15	1·30	TiO_2
ZrO_2	·03	·05	—	—	—	·01	—	—	—	—	ZrO_2
Al_2O_3	5·72	19·79	16·92	13·17	16·00	1·62	28·67	13·38	22·77	18·27	Al_2O_3
Fe_2O_3	·75	3·63	1·70	1·26	4·37	·59	6·29	1·23	2·33	1·66	Fe_2O_3
FeO	·61	3·63	3·41	4·14	—	·11	—	4·88	7·22	6·49	FeO
MnO	·17	·18	·21	·17	·21	·03	·24	·16	·18	·25	MnO
(CoNi)O	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	?trace	(CoNi)O.
BaO	nt.fd.	·08	·15	·04	·03	nt.fd.	·05	·04	·12	·05	BaO
CaO	·85	·68	1·16	6·54	3·02	·21	·33	2·08	1·97	·78	CaO
MgO	·04	·98	1·21	13·34	2·97	·02	3·49	4·33	3 16	2·64	MgO
K_2O	3·15	6·44	5·34	3·12	2·40	·61	6·39	2·92	2·97	2·84	K_2O
Na_2O	1·44	·42	1·57	·48	2·93	trace	·97	1·92	2·14	2·46	Na_2O
Li_2O	nt.fd.	nt.fd.	trace	nt.fd.	nt.fd.	trace	nt.fd.	nt.fd.	nt.fd.	nt.fd.	Li_2O
H_2O at 105°C.	·09	·18	·04	·18	·34	·01	·47	·05	·10	·09	H_2O at 105°C.
H_2O above 105°C.	·27	1·70	·85	·76	1·62	·15	4·34	1·03	1·87	3·37	H_2O above 105°C.
P_2O_5	·03	·15	·16	·24	·12	·03	·16	·15	·17	·15	P_2O_5
FeS_2	nt.fd.	nt.fd.	nt.fd.	nt.fd.	2·57	nt.fd.	1·51	·01	nt.fd.	·60	FeS_2
Fe_7S_8	—	—	—	—	—	—	—	·07	nt.fd.	·72	Fe_7S_8
CO_2	·42	·22	·11	1·44	·09	·23	·04	·11	·04	·08	CO_2
C	—	—	—	—	1·44	—	1·26	—	—	—	C
Total	100·08	100·15	100·15	100·37	100·23	100·20	100·09	100·45	100·17	100·22	Total

Anal. E. G RADLEY.

The following are analyses for Memoir Sheets 43 and 44 :—

20581. Lab. No. 669. Tholeiitic Olivine-basalt.

Shore cliff at Rudha na h-Uamha, S. of the Wilderness, Ardmeanach, Mull. 1 in. sheet 43. 6 in. Argyll. 105 N.E.

20582. Lab. No. 670. Typical Mugearite.

Southward continuation of Ben More Mugearite Lava. Below road. 290 yards E. of Kinloch Hotel, Mull. 1 in. sheet 44. 6 in. Argyll. 95 S.W.

Slice No.	20581	20582
Lab. No.	669	670
SiO_2	49·76	55·76
TiO_2	·94	1·78
Al_2O_3	14·42	16·55
Fe_2O_3	3·95	3·10
FeO	7·77	6·02
MnO	·20	·22
(CoNi)O	nt. fd.	nt. fd.
BaO	·04	·07
CaO	10·22	3·23

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Slice No.	20581	20582
Lab No.	669	670
MgO	5·30	1·08
K_2O	1·83	3·87
Na_2O	2·49	6·28
Li_2O	trace	trace
H_2O at 105° C.	2·04	·80
H_2O above 105° C.	1·03	·95
P_2O_5	·21	·40
FeS_2	·04	nt. fd.
CO_2	·06	·03
Total	100·30	100·14

Anal. E. G RADLEY.

Scotch Iron Ores.

20740 Lab. No. 685.

Garnet Magnetite Rock.—Crystals of Magnetite in a matrix of garnet and opalescent quartz.

Vertical band in Lewisian Gneiss. Opposite Eilean Musimul on S. coast of Iona.

20737. Lab. No. 686.

Magnetite Rock.—Rock composed of magnetite, fibrous hornblende, tremolite, pink garnet, and secondary quartz.

Irregular dissemination in Lewisian Gneiss. Just W. of Port an Fhir-bhreige, on S. coast of Iona.

Slice No.	20740	20737
Lab. No.	685	686
Total Iron	29·40 per cent.	29·68 per cent.

Sulphur and Phosphorus present only in small amounts.

Anal. F. R. ENNOS.

Lab. Nos. 691A and 691B.

Two portions of seam of Ironstone between beds of baked shale and igneous sheets. On shore below H.W.M. 1½ m. 353 yds. W. 23° S. of Kilchoan landing jetty, and ½ m. 78 yds. W. 6° N. of trigonometrical station on Maol Buidhe, Kilchoan, Ardnamurchan. 1 in. sheet 51. 6 in. Argyll. 24 S.W. (*see* p. 97).

Lab. No. 692.

Portion of seam of Ironstone. Just below H.W.M. ¾ m. 180 yds. S.42° W. of Kilchoan landing jetty and 700 yds. E. 13° N. of trigonometrical station on Maol Buidhe, Kilchoan, Ardnamurchan. 1 in. sheet 51. 6 in. Argyll. 24 S.E. (*see* p. 97).

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Lab. No.	691A	691B	692
SiO_2	30·15	17·07	7·73
TiO_2	·33	·42	·16
Al_2O_3	7·89	11·08	3·53
Fe_2O_3	12·20	23·40	·03
FeO	16·73	7·22	4·75
MnO	·53	·67	1·08
(CoNi)O	·06	·05	nt. fd.
BaO	nt. fd.	nt. fd.	nt. fd.
CaO	24·57	25·79	43·49
MgO	3·56	3·88	1·41
K_2O	·28	·28	·26
Na_2O	·41	·45	·42
Li_2O	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	·19	·14	·36
H_2O above 105° C.	·94	1·62	1·20
P_2O_5	1·43	1·90	1·90
FeS_2	·22	·16	4·71
Fe_7S_8	nt. fd.	nt. fd.	·58
CO_2	·99	6·35	28·57
Total	100·48	100·48	100·18

Anal. E. G. Radley.

V.—PALÆONTOLOGICAL WORK

1. England and Wales

The valuable collection of Jurassic Mollusca from the Hudleston collection, presented during the previous year by Miss C. A. Raisin, has been supplemented by a further gift from the same donor. This is a suite of 50 choice invertebrate fossils of a miscellaneous character selected from Miss Raisin's collection.

A study of the Hudleston collection by Mr. C. P. Chatwin showed the necessity for a re-examination of the Kimmeridge and Portland succession at Swindon. Mr. Chatwin and Mr. J. Pringle have paid visits to that locality and have added considerably to our knowledge of the zones represented there. They were successful in establishing the presence of the Rasenia and Gravesia Zones of the Kimmeridge Clay, which Dr. Salfeld had been unable to record. They have also shown that the fauna of the so-called Portland Sands, which there includes many uncrushed ammonites, belongs in reality to the upper part of the Virgatites Zone, thus confirming the suggestion of the late H. B. Woodward that the overlying Swindon Clay is comparable with the Hartwell Clay of Aylesbury. An account

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of their investigation is published herewith as an Appendix (p. 162).

Information obtained by Mr. Pringle before and during the war respecting the important deep boring at Westbury, Wiltshire, has now been made available for publication, and forms the subject of another Appendix (p. 146).

Additional specimens from the deep boring at Great Marlow have been received and examined during the year. It was found that the Lower Greensand there rests on the Oxford Clay, which was penetrated by the boring to a depth of 32 ft. The clay was highly fossiliferous and yielded ammonites and other fossils which Mr. Pringle found to be characteristic of the Renggeri Zone, the middle part of the Oxford Clay. He states that the fauna is practically identical with that obtained from the clay recovered from the chisels at the depths of 1,026 ft. and 1,032 ft. in the Little Missenden boring. The presence of the Oxford Clay in the Great Marlow boring lends strong support to the view that the clay penetrated below the Lower Greensand in the Maidenhead boring also belongs to the same Jurassic formation.

A boring for water at Old Gate, east of Sutton Crosses near Long Sutton, Lincolnshire, was visited by Mr. Pringle and proved to be of much interest. Under a cover consisting of 55 ft. of yellow sand underlain by 140 ft. of grey boulder-clay with flints and chalk-pebbles, Jurassic clays were penetrated. These were proved to a thickness of 106 ft. and were shown by the evidence of fossils to belong to the lower part of the Ampthill Clay and to the Oxford Clay down to its middle portion. This fact throws some light on the position of the western boundary of the Kimmeridge Clay under the superficial deposits of the Wash.

New quarrying operations initiated by Col. A. Arthur Lyle at Barrington, Somerset, have provided an opportunity to study afresh the sections in the Lias of that neighbourhood made classic by the researches of Charles Moore some 50 years ago. Prof. D. M. S. Watson visited the openings and drew attention to the interest of the sections disclosed. Mr. Pringle and Mr. A. Templeman visited Barrington and obtained full details of the Middle and Upper Lias succession. Exhaustive zonal collecting was carried out by Mr. Templeman, and it became possible to ascertain the exact horizon of Moore's principal fossil-beds within a stratigraphical scale based on ammonite-classification. The highest of the strata attributed by Moore to the Middle Lias are found to fall at the basal part of the Upper Lias, in the Tenuicostatum Zone. Numerous fine specimens of the genus *Harpoceratoides* were obtained from the beds above the Exaratum Zone, and it has been found practicable to establish a new and well characterized zonal unit. A complete study of the fossils from these quarries will afford much help in correlating the Upper Lias deposits of this neighbourhood with those of Oxfordshire and other Midland counties.

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Dr. Kitchin and Mr. Pringle visited localities in Oxfordshire, Buckinghamshire and Bedfordshire, obtaining particulars of exposures in the Upper Jurassic rocks and in the Lower Greensand and Gault. Under Mr. S. S. Buckman's guidance they examined an old brick-pit on the Thame Park estate near Thame, situated about one-third of a mile S.S.W. of the railway station. The pit lies within the area coloured as Gault on the geological map, near its junction with the Lower Greensand as represented on the map (Old Series, Sheet 13). The exposures showed a series of fine white-weathering silty clays with a layer of large bluish-grey nodules. The clays appeared to be of estuarine or fresh-water origin. Excepting a few doubtful plant-fragments, no fossils were seen. These beds are considered to represent some portion of the Shotover Sands and are probably of early Wealden age. Excavations in progress in an adjoining field to the north showed the presence of sands belonging to the Portland series. There was no evidence for the outcrop of Lower Greensand shown on the geological map. At the disused Priest End brick-pit, south-west of Thame, the Gault appeared to rest directly on Portland Sands.

At Towersey, east of Thame station, a well and other new excavations gave evidence that the Gault there rests on Purbeck Beds. The lower part of the Gault showed the brecciated character noticed in the lowest part of the overlapping Upper Gault north of Leighton Buzzard. During a visit to the Leighton Buzzard neighbourhood, further evidence was obtained for the overlap of the Upper Gault north of that town.

Mr. Pringle visited Gillingham, Dorset, and examined the Kimmeridge Clay exposed in the large clay-pit near the railway-station. He was able to determine the exact zonal range of the clays exposed in this section. They belong to the upper part of the *Rasenia cymodoce* Zone and the lower part of the overlying *Rasenia mutabilis* Zone. An account of this pit will appear in the forthcoming Memoir on Sheet 313.

Work has been continued in the registration of the Museum collection. Mr. Chatwin has devoted further attention to the collection of Tertiary Mollusca; he has also selected from reserve stores and has registered and named extensive suites of fossils from the Corallian, Kimmeridge and Portland rocks for incorporation in the Museum. This is in preparation for a revision and rearrangement of the cases illustrating those formations. The new materials thus to be utilised are contained in the Hudleston collection and in the additional set of fossils presented by Miss Raisin.

Efforts have been made to find satisfactory methods of preserving pyritized fossils. Mr. S. W. Morgan has treated a large number of specimens with various preservative solutions and has kept full records of these experiments.

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The following specimens in the Museum have been figured, described or mentioned in publications :—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1919. (PUBLISHED 1921.)

A Monograph of the British Ordovician and Silurian Bellerophontacea. (Part ii.)

By DR. F. R. COWPER REED, M.A.

Tremnodiscus fletcheri *Reed*, pl. ix, fig. 6, p. 48.
" murchisoni (*d'Orb.*), pl. ix, figs, 8, 8a, b, 9, 9a, p. 49, (2 specimens).
Bellerophon ledburiensis *Reed*, pl. ix, figs. 14, 14a, p. 56.
Bucaniopsis expansus (*J. de C. Sow.*), pl. x, figs. 1, 1a, 2, p. 60, (2 specimens).
Cymbularia alata (*Portl.*), pl. x, figs. 10, 11, p. 63, (2 specimens).
" carinata (*J. de C. Sow.*), pl. x, figs. 12, 13, 14, p. 66, (3 specimens).
" *cf.* fastigiata (*Lindström*), pl. xi, figs. 11, 11a, 12, p. 70, (2 specimens).
Salpingostoma ? infundibulum *Reed*, pl. xii, fig. 5, p. 78.
Trematonotus aymestriensis (*J. de C. Sow.*), pl. xii, figs. 7, 8, 8a, p. 79, (2 specimens).
" dilatatus (*J. de C. Sow.*), pl. xiii, fig. 1, p. 80.
" portlocki *Reed*, pl. xiii, figs. 4, 4a, b, p. 83.
Zonidiscus sp., p. 74, (3 specimens).

A Monograph of the Fossil Insects of the British Coal Measures. (Part i.)

By MR. H. BOLTON, M.Sc., F.R.S.E.

Orthocosta splendens *Bolton*, pl. i, figs. 2a, b; text-fig. 1, p. 28, (2 specimens).
Pteronidia plicatula *Bolton*, pl. i, figs. 3a, b; text-fig. 2, p. 30, (2 specimens).
Cryptovenia moyseyi *Bolton*, pl. ii, figs. 1a, b; text-fig. 4, p. 36, (2 specimens).
Boltoniella tenuitegminata (*Bolton*), pl. iii, fig. 4, p. 56.
Pseudofouquea cambrensis (*Allen*), pl. iv, fig. 8a; text-fig. 22, p. 73.

The Pliocene Mollusca of Great Britain. Volume II. (Part ii).

By MR. F. W. HARMER, M.A.

Acrybia smithi (*Brown*), pl. lv, fig. 9, (2 views), p. 699.
Natica multipunctata *S. V. Wood*, pl. lv, fig. 12, (2 views), p. 677.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, VOLUME LXXVI.

The Cambrian Horizons of Comley (Shropshire).

By MR. E. S. COBBOLD.

Micromitra (Paterina) phillipsi *Holl.*, pl. xxi, figs. 1, (2 views), 2, (3 views), p. 329, (2 specimens).
" " rhodesi *Cobbold*, pl. xxi, figs. 4a, b, c, 6, (2 views), p. 330, (2 specimens).
" " kingi *Cobbold*, pl. xxi, figs. 7, (2 views), 8a, b, p. 330, (2 specimens).

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Micromitra (Paterina) minor *Cobbold*, pl. xxi, fig. 15, p. 333.
" " " *var.* gibbosa *Cobbold*, pl. xxi, fig. 17, (2 views), p. 334.
" sp., pl. xxi, fig. 9, (3 views), p. 330.
Walcottina lapworthi *Cobbold*, pl. xxi, figs. 23a-c, 24a, b, 25, p. 336 (2 specimens).
Obolus ? linnarssoni *Cobbold*, pl. xxii, fig. 23, p. 338.
Lapworthella nigra *Cobbold*, pl. xxiv, figs. 1, 3, 4, p. 360, (3 specimens).
Scenella elevata *Cobbold*, pl. xxiv, fig. 36, (2 views), p. 364.
Escasona ? spp., pl. xxiv, figs. 47, (3 views), 48, (3 views), p. 368.
Leperditia ? dermatoides *Walcott* (?), p. 368.

In the Quarterly Journal of the Geological Society, Volume LXXVII.

A New Species of Blattoid (Archimylacris) from the Keele Group (Radstockian) of Shropshire.

By Mr. H. Bolton, M.Sc., F.R.S.E.

Archimylacris pringlei *Bolton*, pl. i, figs. 1, 2; text-fig. 1, p. 24, (2 specimens)

The Evolution of certain Liassic Gasteropods, with special reference to their Use in Stratigraphy.

By Miss A. I. McDonald, M.Sc., and Dr. A. E. Trueman.

Katosira trivia (*Tate*), pl. xxii, fig. 2, p. 335.
Promathildia tenuicostata (*Portl.*), pl. xxii, fig. 6, p. 336
" ligaturalis (*Tate*), text-fig. 23, p. 338.
Procerithium liassicum (*Tate*), text-fig. 6b, p. 307.
" dayi (*Tate*), p. 314.
" raricostati (*Tate*), p. 314.
" subfistulosum (*Tate*), text-fig. 10, p. 320.
Zygopleura nuda (*Tate*), text-fig 16, p. 329.
" semitecta (*Tate*), text-fig. 20, p. 332.
Bourguetia deshayesea (*Terquem*), p. 339

In the Geological Magazine, Volume LVIII.

Notes on the Fauna of the Lower Devonian of Torquay.

By Dr. F. R. Cowper Reed, M.A.

Stropheodonta murchison (*d'Archiac and de Verneuil*), p. 314.
" gigas (*M'Coy*), p. 315, (2 specimens).
Chonetes plebeia *Schnur*, p. 316, (6 specimens).
" sarcinulata (*Schloth.*), p. 316.
Camarotœchia daleidensis (*Roemer*), p. 317, (4 specimens).
Tropidoleptus rhenanus *Frech*, p. 321, (10 specimens).

In Proceedings of the Geologists' Association, Volume XXXII.

On the Beds at the Base of the Ypresian (London Clay) in the Anglo-Franco-Belgian Basin.

By Dr. L. Dudley Stamp.

Melanopsis ancillaroides *Desh.*, pl. 2, fig. 8, p. 97.

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In Type Ammonites, Volume III., 1920–1921.

By Mr. S. S. Buckman.

Korythoceras korys *S. Buckm.*, p. 17, (2 specimens).
Pavloviceras omphaloides (*J. Sow.*), pl. cxcv, figs. 1, 2, 3, 3a, p. 18, (2 specimens).
Sagitticeras sagitta *S. Buckm.*, pl. cclx, p. 19.
Proplanulites majesticus *S. Buckm.*, pl. ccxxvi, figs. 1, 2, p. 34.
„ basileus *S. Buckm.*, pl. cclii, figs. 1, 2, p. 34.
„ laevigatus *S. Buckm.*, pl. ccxxxii, figs. 1, 2, p. 34.
„ sp., p. 34.
„ ferruginosus *S. Buckm.*, p. 34.
„ opimus *S. Buckm.*, p. 35, (2 specimens).
„ *aff.* arciruga (*Tornquist*), p. 35, (2 specimens).
„ polonicus *S. Buckm.*, p. 35.
„ occultus *S. Buckm.*, p. 35.
„ latus *S. Buckm.*, p. 35.
„ koenigi (*J. Sow.*), p. 36, (3 specimens).
„ laboratus *S. Buckm.*, p. 36.
„ involutus *S. Buckm.*, p. 36, (4 specimens).
„ lentus *S. Buckm.*, p. 36.
„ subcuneiformis *S. Buckm.*, p. 37, (2 specimens).
„ auriculatus *S. Buckm.*, p. 37, (2 specimens).
„ capistratus *S. Buckm.*, pl. ccxiii, figs. 1, 2, p. 37, (2 specimens).
„ rudis *S. Buckm.*, p. 37, (3 specimens).
„ arciruga (*Teisseyre*), p. 38.
„ oidaleus *S. Buckm.*, p. 38, (3 specimens).
„ stiphrus *S. Buckm.*, p. 38, (2 specimens).
„ petrosus *S. Buckm.*, p. 38.
„ lyprus *S. Buckm.*, p. 38, (2 specimens).
„ tridens *S. Buckm.*, p. 38.
„ excentricus *S. Buckm.*, p. 39, (2 specimens).
„ partitus *S. Buckm.*, p. 39.
„ rufus *S. Buckm.*, p. 39.
„ fulvus *S. Buckm.*, p. 39, (2 specimens)
„ fracidus *S. Buckm.*, p. 40, (2 specimens).
„ capularis *S. Buckm.*, p. 41, (2 specimens).
Crassiplanulites crassicosta *S. Buckm.*, pl. ccxxviiiA; pl. ccxxviiiB, figs. 1, 2, p. 42.
„ crassiruga *S. Buckm.*, pl. ccliii, p. 42.
Tulites subcontractus (*Morris and Lycett*), p. 45.
Madarites madarus *S. Buckm.*, p. 46.
„ glabretus *S. Buckm.*, p. 52.
Bullatimorphites bullatimorphus *S. Buckm.*, p. 47.
Morrisites morrisi (*Oppel*), p. 49.
Gowericeras metorchum *S. Buckm.*, pl ccliv, figs. 1, 2.

In Jahresbericht (7) des Niedersächs. geol. Ver. zu Hannover (Geol. Abteil. der Naturhist. Gesellsch. zu Hannover), 1914.

Ueber einige stratigraphisch wichtige und einige seltene Arten der Gattung Perisphinctes aus dem oberen Jura Nordwestdeutschlands.

By Prof. Hans Salfeld, Ph.D.

Perisphinctes *cf.* biplex (*J. Sow.*), p. 241.
„ wartae *Bukowski*, p. 249, (3 specimens).

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In Zeitschr. der Deutsch. Geol. Gesellsch., Volume LXVII., Jahrg. 1915.

Monographie der Gattung Cardioceras Neumayr et Uhlig. Teil i, Die Cardioceraten des oberen Oxford und Kimmeridge.

By Prof. Hans Salfeld, Ph.D.

Cardioceras prae-bauhini *Salfeld*, pl. xvii, figs. 5a, b, p. 179.
„ serratum (*J. Sow.*), pl. xviii, figs. 1a, b, c, 2a, b, p. 172, (4 specimens).
„ cricki *Salfeld*, pl. xix, figs. 3a, b, c,—6a, b, c, p. 191, (4 specimens).
„ kitchini *Salfeld*, pl. xix, figs. 8a, b, c,—17a, b, c, p. 189, (10 specimens).

In Palæontographica, Volume LXII., Stuttgart, 1917.

Monographie der Gattung Ringsteadia (gen. nov.).

By Prof. Hans Salfeld, Ph.D.

Ringsteadia anglica *Salfeld*, pl. xiii, p. 76, (3 specimens).
„ pseudo-cordata (*Blake*), p. 80, (2 specimens).

2. Scotland.

The materials accumulated during the year were chiefly dealt with by Dr. G. W. Lee in the Survey Office, but as in previous years the Ammonites have been submitted to Mr. S. S. Buckman and the Carboniferous Plants to Dr. R. Kidston. Prof. A. C. Seward has furnished a report on Tertiary Plants collected during a previous year in Mull.

The Carboniferous fossils examined by Dr. G. W. Lee have revealed some interesting points. A large and varied collection made by Mr. Manson in the Douglas district shows the presence of faunal assemblages having the features of the faunas which elsewhere characterise respectively the Hollybush Limestone, the Blackbyre Limestone, and the shale associated with the Blackhall Limestone. Opportunity may be taken here of mentioning the discovery of a remarkable fossil, which is not only new to the Scottish Carboniferous rocks, but is probably also new to science. It is an astreiform coral whose external characters are curiously like those of the Lower Palaeozoic genus *Syringophyllum*. Only one specimen is known, obtained from the core of a boring through the Upper Limestone Series, near Lenzie.

The examination of the Scottish Mesozoic Rocks has been continued, and Mr. S. S. Buckman is still engaged upon the critical study of the large number of ammonites collected from the classical localities of the north-east coast. A puzzling statement in Judd's account of the Liassic sequence in Tobermory, Mull, has now been elucidated; his reference to "*Ammonites oxynotus*" is probably due to the mistaken identification of some other discoid ammonite—perhaps a *Tragophylloceras* of the Ibex Zone. The Tobermory sequence therefore does not begin as low down as Judd thought.

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Dr. G. W. Lee identified an outcrop of the Raasay Ironstone in Ardnamurchan by finding the typical fauna of *Harpoceras*, *Dactylioceras*, and Belemnites (*see* p. 97).

VI.—MUSEUM OF PRACTICAL GEOLOGY

Considerable progress has been made in the organisation and expansion of exhibits. The Geology of the London District is now illustrated by suitable specimens and a model, recoloured to correspond with the latest 6-inch geological maps, whilst cases of specimens showing the uses of refractory materials, sands, clays and cements are now on exhibition. Exhibits to show the results of recent Survey work have been planned and are in course of development.

In the Mineralogical Department the work of investigating the petrology of the British iron ores has made considerable progress and cases have been arranged to illustrate various 'Special Reports.' Additions have been made to the collection of gemstones with a view to bringing it up-to-date.

Revision-work in the collections has made good progress, and a considerable amount of registration and re-organisation of the older collections has been accomplished.

The public have continued to use the collections, the Library and the Map Room in increasing numbers and a large amount of time has been devoted to dealing with enquiries.

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APPENDIX I

The Retreat of the Lake District Ice-Cap in the Ennerdale Area, West Cumberland

By E. E. L. Dixon, B.Sc., A.R.C.Sc.

INTRODUCTION

Gilbert, Tarr and others have described the deposits that are being built up at the front of stationary ice-sheets, such as those of Alaska, where subglacial streams emerge and cast down their overload of gravel and sand. The coarse material accumulates in masses that are banked against the ice behind, and slope down forward and laterally to a more or less lobate margin. On land the masses are fans, characterized by a uniform slope from summit (at the mouth of the stream) to margin. Those laid down under water are deltas with the gently-sloping top and the steeply-sloping front, or 'foreset' beds, usual in deltas. The masses that have survived a retreat of the ice often retain 'back' or 'ice-contact' slopes that are noticeably steep where they have been supported by a steep ice-front.

Similar fans and deltas have been recognised in the Pleistocene Drift of Europe, notably Scandinavia, and of America, in the course of the work of de Geer and of a number of American geologists. They have been variously named. Being frontal deposits, they together with certain irregular mounds and ridges of gravel and sand are all grouped by some as kames. As, however, they mark the outlets of definite and persistent subglacial streams they may usefully be distinguished from other kames and will here be spoken of as outwash-fans and outwash-deltas. In America, for deposits of either class that are "associated with an esker or esker-like chain made in the ice-sheet at the same time," Woodworth[1] has used the term 'esker-fans.' As these may evidently, from their descriptions and figures, be exactly paralleled here and the term implies the close relation with the eskers (called 'feeding-eskers' in America), it will be adopted, but for fans only; those outwash-deltas with which an esker in the position of a feeding-esker has been preserved will be called esker-deltas. Other names that have been used for either or both classes with or without related eskers, such as 'sand-plains,' 'apron-plains,' 'wash-plains,' are unsuitable for the Cumbrian examples, and the same may be said of de Geer's term 'marginal terraces' (Randterrasser)[2] for outwash-deltas.

As eskers have been the subject of much controversy it may be remarked that the few examples found near Ennerdale make wide angles with the supposed trends of the ice-front and appear to mark the courses of subglacial streams. Similar, but more

[1] *Bull. Essex Inst., Salem*, vol. xxix, 1898, p. 79.

[2] *Geol. Foren. Forh., Stockholm*, bd. 31, 1909, p. 554; *ibid.*, bd. 44, 1922, tav. I.

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definite, evidence is yielded at Newport, Salop,[1] though it is not suggested that all eskers are of this nature. However, now that such eskers are regarded by many as formed at or near the ice-front during periods of steady retreat, the distinction between kames and eskers would appear to resolve itself largely into one of elongation along or across the ice-front, dependent on rapidity of retreat.

The dip of the gravels is seldom seen. In Kelton Head out-wash-fan, which, owing to its elongation might be termed an esker, it is parallel to the steep side of the ridge.

Other deposits of use in unravelling the conditions of ice-retreat near Ennerdale are the deltas, now left on the hillsides, but originally thrown down by glacier-fed streams in bodies of standing water. The forms and the uniformity of height sufficiently show that these masses of gravel are deltas. Some of them have been referred by Prof. A. H. Green[2] to a period of marine submergence, a view supported by Prof. Gregory[3] to whom I am indebted for pointing out Green's account. But it is known that during the Glacial period the Irish Sea has been occupied by a great ice-sheet, which has invaded the Cumbrian coastal plain, and, as Mr. B. Smith shows,[4] has risen high against the fells behind the plain, impounding lakes in the dales similar to the classic examples of Glen Roy and Cleveland described by Jamieson and Prof. Kendall. That the Ennerdale deltas have been deposited in such a lake is demonstrated by the discovery of an overflow-channel at the same height as that of one set of deltas. Further, none of the gravels have yielded marine organisms; and the probable variations in height of the lake-level can be correlated with known movements of the Irish Sea ice.

Laminated clays, like those of glacier-lakes, occur in Ennerdale, but terraces and notches or old lake-cliffs are poorly developed. The burden of proof that lower Ennerdale to a height of 800 ft. above O.D. has been under water rests on the presence of deltas.

PHYSICAL FEATURES

The ground examined is the greater part of that shown on the map (Fig. 5). Around the present Ennerdale Water and in its higher reaches Ennerdale is a deep, steep-sided, rock-walled and U-shaped valley. Lower Ennerdale, *i.e.*, the valley of the Ehen, which drains the lake, is much wider, is mantled with drift, and its northern side is comparatively low; but still it contrasts strongly with the wide, gentle slopes of the northerly draining Marron valley, which commences immediately to the north. Thus there is a great right-angled re-entrant in the front of

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, pp. 19, 20.

[2] 'Physical Geology,' ed. 3, 1882, p. 633, fig. 224.

[3] *Geol. Mag.*, 1922, p. 37.

[4] *Quart. Journ. Geol. Soc.*, vol. lxviii., 1912, pp. 412, 423–44, 447.

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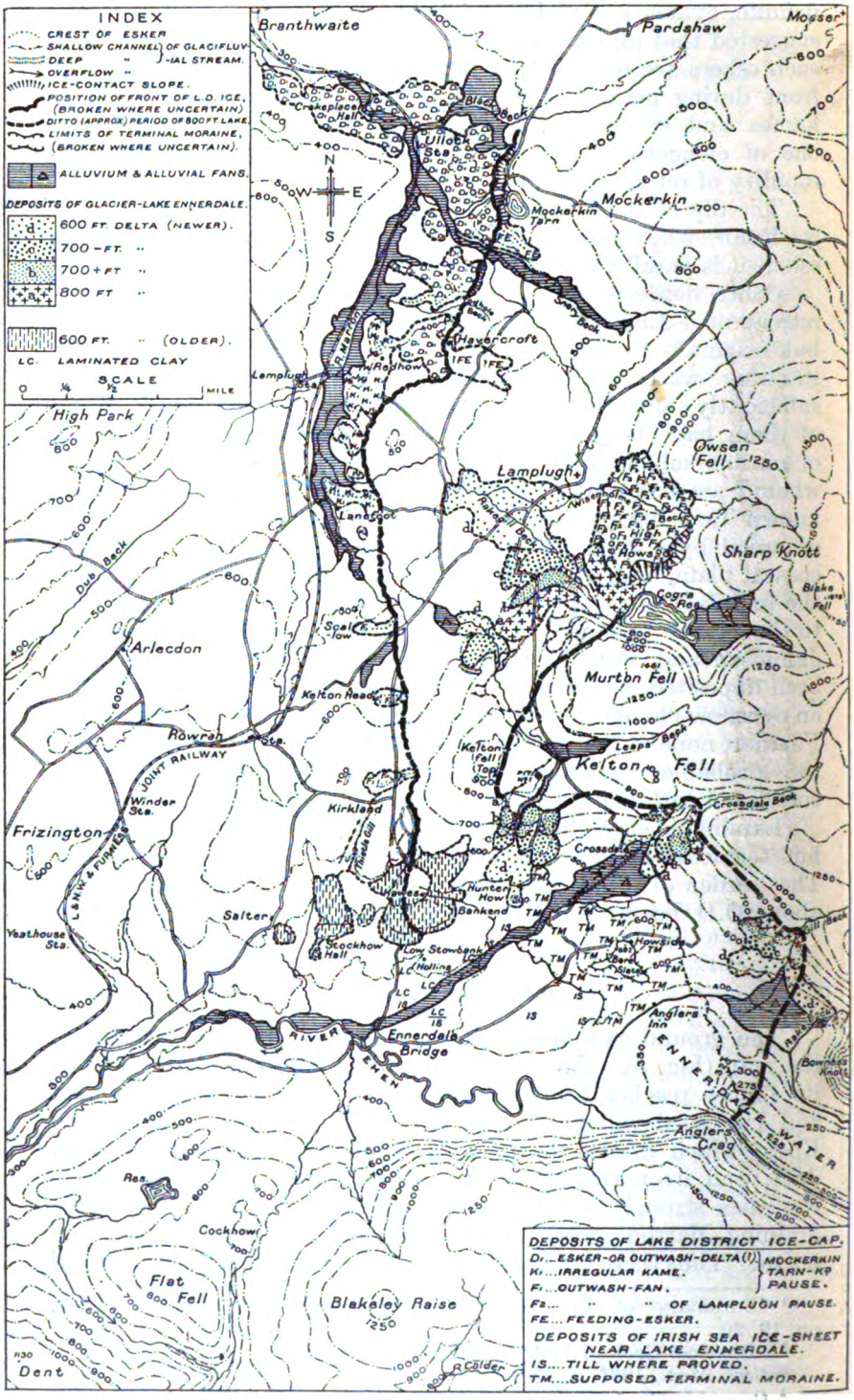

FIG. 5.—*Map showing Stages in the Retreat of the Lake District Ice-Cap in the Ennerdale Area.*

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the fells, with its point at the lower end of Ennerdale Water. Running west is the high southern side of the Ehen valley, while northward extend the fells bordering the Marron valley. In this re-entrant were imprisoned the waters of glacial Lake Ennerdale, the forerunner of the present lake.

THE OUTWASH-FANS AND SUPPOSED OUTWASH-DELTAS

Most of these deposits occur in a belt of kames that has been traced from Kirkland to Mockerkin Tarn, but the finest example of an outwash-fan rises behind Lamplugh. All these kames, and also the deltas of the glacial lake, consist so largely of slate-gravel that they doubtless were formed by waters from the Lake District ice-cap. They contrast with the gravels, found in parts of the district, from the melt-water of the Irish Sea ice, in which Coal Measures debris, notably Whitehaven Sandstone, and New Red breccia are always predominant. Though the former include in places Coal Measures material, the quantities are insignificant.

The Mockerkin Tarn–Kirkland Kame-Belt.–From Mockerkin Tarn to Lanefoot the deposits are almost continuous and appear to have been subaqueous, as they have steep fronts and fairly flat tops at a height of about 400 ft. above O.D. Most have been formed by persistent streams. These are doubtfully called deltas (' esker- or outwash-deltas ? ') on the map because the existence of water standing at that level at the time of their formation has not yet been confirmed, and their flat tops might possibly be the result of later submergence.

The masses that have most clearly been formed at an ice-front are the two northernmost, at Mockerkin Tarn and between Snary and Todhole Becks. These are bounded on the east by steep, aligned slopes, which are inferred to be ice-contact slopes, running N. and S. parallel with the trend of the kame-belt. Their other margins are lobate. Like the sand-plains of New England and similar formations elsewhere, their tops are pitted with kettle-holes. At Mockerkin Tarn a short steep-sided esker (FE, Fig. 5) runs almost at right angles to the ice-contact slope, its top level with the top of the kame, in which it expands and is immediately lost. Evidently it corresponds, in its relations to the kame, to the ' feeding-eskers ' of New England and other places, and the kame is either an ' esker-delta ' or an ' esker-fan.'

Mockerkin Tarn lies in the low ground at the angle between the feeding-esker and the ice-contact slope, presumably therefore in the space left by the melting-ice. The Tarn now has no visible outlet, but formerly its level has been much higher and its overflow has cut a narrow deep channel through the ice-contact slope and straight across the kame in a S.W. direction, down to within a few feet of its present level.

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Westward from the ice-contact slope the kame narrows as far as Ullock, where it appears to end. Probably the kame was not cast forth wholly from an ice-front along its eastern margin, but during slow retreat while the front was crossing the ground between Ullock and Mockerkin Tarn.[1] Thus we may explain also the elongation, at right angles to the supposed trend of the ice-front, of many of the kames to the south, and especially the relations of an esker to the kame between Snary and Todhole Becks. This esker is a narrow steep-sided ridge that commences as a spur of the kame and runs out westward clear of the main mass. A sharp zig-zag bend in its crest (indicated on Fig. 5 by a dotted line) links it with many typical eskers, but its position is that of a distributary of the kame. It was deposited, apparently, as the ice-retreat was slowing up for the stand at the Mockerkin Tarn line.

From Lanefoot to Kirkland there are merely three small ridges running east and west, at Scallow, Kelton Head and Kirkland. These, however, are in line with the kames to the north, and in the other direction, beyond Kirkland, we find the evidence cited later of the former existence of a N. to S. ice-front. The Kelton Head ridge has the same form as some of the outwash-fans near Newport, Salop. It is pointed-oval in plan, highest at the point (eastern end) where it terminates in a steep slope, the ice-contact slope, and it spreads as it falls gradually westward. The westward fall of the other ridges is less regular. All three are concluded to be outwash-fans, in their elongation approaching eskers.

The Lamplugh Outwash-Fan.—This unusually well-developed fan (F 2) stands at the foot of the fells above Lamplugh, where the two deep valleys of the Wisenholme and Rakegill Becks emerge on the western plain, Its summit at High Hows stands at over 1,000 ft. at the top of a long north-western slope which rises from below 700 ft. on the plain, with an average gradient of 1 in 7. The south-eastern slope is much steeper (1 in 3) but shorter; it is half a mile wide (from N.E. to S.W.) and near High Hows over 100 ft. high. It is partly the side of a knoll of slate on which the half-cone of gravel has been dumped, but it is as steep where made of gravel as where made of slate.

Form, position and height, and the nature of its material show that this foot-hill is not a moraine of former valley-glaciers in the valleys of the becks—it can have been built up only as the fan of a great subglacial stream debouching at High Hows at a height of at least 1,000 ft. from a wall-like N.W.-facing ice-front (not shown on map). The south-eastern slope is the ice-contact slope, and the steady fall of the north-western slope

[1] The gravels between Ullock and Branthwaite, though lettered D_1 on the map like the kame, have been found, since the map was made, to belong to an entirely different and later, series (not shown elsewhere on the map) extending down the Pardshaw valley and the Marron below Ullock.

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indicates subaerial conditions of deposition at least as low as 700 ft.

The height of the ice-front and the size of the stream imply that the ice was a large mass on high ground—doubtless the Lake District ice-cap.

The material of the half-cone, as exposed along Wisenholme Beck, is largely slate-gravel, tumultuous, earthy or bedded, but includes also loam and clay. The presence in the lower parts of the fan, here and elsewhere, of great blocks of Carboniferous limestone from the outcrop to the west shows that at some period before the separation of the Lake District ice-cap from the Irish Sea ice-sheet the latter had invaded the front of the fells to heights of over 800 ft.

No other fans are yet known to have been thrown down during the Lamplugh pause of the ice-front, but the lake-deltas that will be described later give the approximate position of the ice-front either at the end of the pause or somewhat later.

GLACIAL LAKE ENNERDALE

During the Mockerkin Tarn–Kirkland Pause.—Glacifluvial waters draining away from the front and sides of subaerial fans which they are building up may cut gullies and channels, radiating from the fans, in the surrounding land-surface. On the disappearance of the ice these hollows as a rule are left dry. Dry hollows, Thistle Gill and an unnamed network of channels south of Kirkland, drain south from the Kirkland outwash-fan, one from each end, down the side of Lower Ennerdale. The network leads to a large group of deltas of slate-gravel halfway down the valley-side, extending to Low Stowbank. The tops of the deltas are just below the 600-ft. contour, and their fronts are steep banks that contrast strongly with the gentle slopes below.

The channels south of Kirkland are remarkable on account of their depth and looping. The larger of them are steep-sided, flat-bottomed gullies cut in Skiddaw Slate, to a depth of 50 ft. for much of their course. The trickles of water in them probably never cover the bottoms and certainly are not capable of much erosion. The shallower channels are dry, and several of these are loops, or alternative courses, of the larger ones, cut through higher ground.

Both Thistle Gill and the Kirkland channels arise immediately south of the Kirkland fan—they do not breach the water-shed between the Ehen and Marron valleys, on which the fan rests. Neither, therefore, appears to be an overflow-channel into Lower Ennerdale from a glacier-lake in the Marron valley, even should such have existed at the time at the necessary height, of which there is no evidence. They have been cut by waters draining from the fan or, in the case of the network of channels below its eastern end, possibly from the Lake District ice-front there directly.

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The number and the looping of these eastern channels seem to require for explanation streams that have been limited in position by the presence alongside them of an ice-front varying somewhat in its stand. For only the easternmost channel follows a free path along the bottom of the gentle hollow of the valley-side in which the channels lie. The rest have been cut at different distances up the western slope of the hollow. The depth of each is apparently a measure of the time that the ice-front has lain alongside, before retreating or advancing and thus allowing or forcing the stream to take a lower or a higher path. Possibly, however, the ice-front was stationary, and the stream at different times found different paths along, or just within, its margin. In either case the trend of the channels points to a N. and S. trend of the ice-front.

The deltas at the mouths of the Kirkland channels have been built up in water standing at about 600 ft., and as the wind-gap between Dent and Flat Fell, in the southern wall of Ennerdale, has the characters of an overflow of a glacier-lake and the level of its sill is a little under 600 ft. above O.D., the water is inferred to have been a lake held up by an ice-front to the west across lower Ennerdale and abutting against Dent.

At the end of, or after, the Lamplugh Pause.—Between Lamplugh and Bowness Knott a number of deltas of streams now dead or greatly reduced have been found banked against the hillsides. They differ from the deltas just described in being terraced or compound, each consisting of two, three or four deltas at the following heights :—800 feet; an undetermined height well over 700 ft. (700 + ft., Fig. 5); one somewhat under 700 ft. (700 — ft.); and 600 ft. Each component cuts through that above : the level of the water in which they were deposited was falling by stages. As the height of the lowest stage is the same as that of the hollow between Dent and Flat Fell mentioned above, this water is inferred to have been that of a lake, not that of the sea. Overflows corresponding to some or all of the higher stages may have existed between Flat Fell and Blakeley Raise, as would appear from the contour-lines, but this ground has not yet been examined.

In several cases it is probable that the streams that threw down these deltas had close relations to the ice-cap. The Rakegill Beck deltas lie in, and just outside, the gap between the Lamplugh outwash-fan and Murton Fell, and the 800-ft. member cuts into the side of the fan. The delta is therefore newer than the fan. On the other hand the same member is bounded eastward by a back-slope (shutting in the Cogra Res.) in line with the ice-contact slope of the fan. The back-slope may be merely the remains of the southern part of the latter slope, in which case much of the 800-ft. delta would be merely the southern part of the fan below the notch cut at the 800-ft. level. More probably, however, the presence of the back-slope means that the 800-ft. delta has been banked against an ice-front, that

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is, the ice-front remained in the position it had occupied during the deposition of the fan for a further period, during which the 800-ft. delta at least was formed. In this view, the 800-ft. member is an outwash-delta.

The forms of this and the lower members throw light on the conditions existing in the glacier-lake. The upper surface of the 800-ft. delta is pitted with several kettle-holes; presumably, therefore, blocks of ice were buried in its gravels when it was laid down. All the members except that at 600 ft. are deflected sharply southward on emerging from the hills on to the coastal plain, showing that a strong southerly shorewise current has existed during the early stages of the lake but has disappeared before the close.

Turning now to the more southern terraced deltas we find that all the members are banked against higher ground. But though none of their slopes, therefore, appear to indicate ice-contact, other evidence of the proximity of the ice-cap is clear in one case, that of the lobate delta that hangs on the northern side of Lower Ennerdale above Hunter How. The streams that carried the material of this delta to the lake are dead and could not revive under conditions merely of increased precipitation. Above the delta an E. to W. spur, beginning as Kelton Fell on the east and culminating in Keltonfell Top, runs out from the main mass of the fells and forms the watershed between Ennerdale and Leaps Beck, a tributary of the Marron. The chief feeders of the delta were two parallel streams that flowed right across this spur (one on either side of Pit No. 1 of Keltonfell Mine), the eastern of the pair cutting a steep-sided trench, 30 ft. deep at the crest of the spur, through hard Skiddaw Slate. The western stream, which is known from its delta to have been short-lived and may have completely preceded the other, has cut a shallower trench a few yards away in gravels. Neither trench is deep enough to divert the drainage of Leaps Beck under normal conditions. The shallower begins above the level of the beck and its course is uphill for some distance, until the crest of the spur is reached. The deeper may also rise at first, for it starts at grade at the level of the beck's alluvium, and if it does not rise it is difficult to understand why it has not drained the beck. Unfortunately its thalweg is obscured by trees and a mineral railway.

These trenches show another abnormal feature. On the Ennerdale side of the spur each runs obliquely to the slope of the ground. The deeper cut, in particular, turns nearly west and almost contours the valley-side. And each bends sharply at the commencement of its delta into the course that would be taken by a free current of water descending the maximum gradient, a course which is then maintained.

The streams that have cut these trenches would appear to be possible only if ice were covering or bordering the anomalous parts of their courses. Such an explanation as the diversion

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of Leaps Beck by a snowdrift or ice-barrier across its valley below the intakes of the streams is clearly insufficient. Notably it completely fails to account for the course of the streams along, instead of down, the Ennerdale slope. The streams may conceivably have been marginal to a retreating ice-lobe, but as their channels appear to be similar—in cutting across the pre-glacial topography and in draining both ways—to a hollow described by de Geer,[1] which he ascribes to a swift subglacial stream under considerable hydrostatic pressure, this explanation has been adopted. In Fig. 5 the ice-front is represented as crossing the streams where their trenches turn directly downhill.

The deltas of the streams have been deposited at the following heights :—on the west, possibly at 800 ft., and at 700+ ft.; on the east, at 700+ ft., 700— ft. and 600 ft. The eastern 700+ ft. delta is kettle-holed. No shorewise drift is apparent.

Farther east in Ennerdale two other deltas, each terraced at the four heights, have been built up where Crossdale and Gill Becks emerge on the valley-side. In their cases it is less obvious that the ice-front has had the position shown in Fig. 5, *i.e.*, on the shore of the 800-ft. lake, but in each case certain peculiarities in development of the delta at that level suggest a feeder independent of the present beck. The chief conclusion, however, to be inferred from their presence in Ennerdale is that while an ice-cap sufficient to nourish the streams that deposited the Hunter How delta still lingered on the high ground to the north, Ennerdale west of Gill Beck was clear, along the north side of the valley at least, of Lake District ice.

This conclusion does not run so counter as appears at first sight to the view that towards the end of the Glacial Period the dales have been occupied by valley-glaciers. For the evacuation of Lower Ennerdale may have been precipitated by the standing water at the ice-front floating off bergs, as has been suggested by Shaler to account for the clearance of the Narragansett Basin in New England.[2]

The indentation of the ice-front at Ennerdale during the higher stages of the lake, viewed broadly, may not have been great, for a delta at Rake Beck, north of Bowness Knott, consists of the 600-ft. member only. Possibly this place was still covered by the Lake District ice when the lake stood higher, as suggested in Fig. 5.

The Cause of the Changes in Level.—The group of deltas south of Kirkland indicates a lake-level of 600 ft. only, apparently at the time of the Kirkland pause. The terraced deltas were formed in a lake whose level fell from 800 ft. to 600 ft. and whose period followed the Lamplugh pause. Were the Kirkland deltas deposited after or before the terraced deltas ? The first supposition postulates a re-advance of the ice-front

[1] *Geol. Foren. Forh., Stockholm*, bd. 31, 1909, p. 534.

[2] 'The Geology of the Narragansett Basin,' *Mon. U.S. Geol. Surv.*, 3, 1899, p. 68.

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from the stand at Lamplugh to that at Kirkland, but it needs no change of lake-level between the closing stage of the terraced deltas and the period of the Kirkland deltas. The second supposition postulates retirement of the ice-front from the Kirkland to the Lamplugh stand, but involves a raising of the lake-level toward the end of the latter pause from 600 to 800 ft. and a subsequent fall to 600 ft. again.

The first supposition therefore is the simpler, and a re-advance of the ice-cap is likely enough, but the evidence available negatives strongly the corollary that the Lamplugh fan, the terraced deltas and the channels of glacifluvial streams, all in the path of the re-advance, have been invaded and covered by ice. The deposits have undisturbed contours and the channels are free of drift. On the other hand after the evacuation of Lower Ennerdale by the Lake District ice the Irish Sea ice appears to have readvanced to such an extent that it may well have closed the outlet of the glacier-lake at 600 ft. between Dent and Flat Fell, and thus have raised the lake-level to 800 ft., with an outlet over the ice or between Flat Fell and Blakeley Raise.

The evidence of this re-advance is as follows. Lower Ennerdale is mantled with western Drift full of Whitehaven Sandstone and other Carboniferous rocks. The orientation of the drumlin features suggests that the transporting ice has moved straight up the valley, and the western Drift comes to an end at the present lake as a moundy belt (TM, Fig. 5) that crosses the valley from side to side and appears, from its form and its boulder-strewn, part gravelly or sandy, character to be a terminal moraine.[1] As the Drift reaches a height of nearly 700 ft. at Howside the ice that carried it may easily have been higher than 800 ft. at Flat Fell, 3 miles to the south-west.[2]

Ennerdale Water, then, is presumably dammed up, not by the terminal moraine of a Lake District valley-glacier, but by this western Drift, and is a direct descendant of the glacier-lake formerly held up by the ice that has carried the Drift into the dale. The shape of the lake-basin (*see* subaqueous contours, Fig. 5) shows that the barrier extends beneath the present lake as far as Anglers Crag, but not beyond, and it is probably not a coincidence that at Gill Beck, N.E. of this place, evidence of the 800-ft. lake-level, so far as known, ceases. As previously suggested, the high-level lake may there have been limited by the front of the still-lingering Lake District ice, which may also have stopped further advance of the invading tongue of debris-laden Irish Sea ice. Between the two ice-fronts at the period of maximum readvance lay the narrow 800-ft. lake.

[1] In Fig. 5 it is shown as far south as the Anglers Inn, and Mr. Maden finds that it continues, bounding the lower end of the lake.

[2] An advance of an ice-lobe into a hollow occupied by a marginal lake has been shown by Mr. E. M. Anderson ('The Geology of Mid-Strathspey and Strathdearn' *Mem. Geol. Surv., Scotland*, 1915, p. 62) to need a certain 'head' of ice, dependent on the depth of the water and the load of debris carried by the ice.

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The readvance of the Irish Sea ice may have been due directly to relief of counter-pressure on the retreat of the Lake District ice, but it is equally possible that it has had an independent cause.

CONCLUSIONS

1. Towards the end of the Glacial Period the Lake District ice-cap shrank away from the Irish Sea ice-sheet along a line, at present unlocalised, which lay along, or west of, the Marron River above Ullock.

2. During its retreat the ice-cap paused along the line Mockerkin Tarn–Kirkland, and later at the foot of the fells at Lamplugh, at each pause depositing kames but no other form of recessional moraine.

3. The Mockerkin Tarn–Kirkland kame-belt includes outwash-fans and probably outwash- and esker-deltas, the deposits subaerial and subaqueous respectively, of more or less persistent subglacial streams. The supposed deltas suggest that water was standing in the Marron valley at about 400 ft.

4. The few eskers also present make wide angles with the line of the ice-front and mark the courses of subglacial streams.

5. During the Mockerkin Tarn–Kirkland pause, water was impounded as a glacier-lake by the Irish Sea ice in Ennerdale to a height of 600 ft., its outlet being to the south between Dent and Flat Fell.

6. The Lamplugh kame is an outwash-fan of a great subglacial stream that has debouched at a height of about 1,000 ft. from a wall-like ice-front across the Wisenholme and Rakegill Becks. The country immediately to the west, down to 700 ft. at least, was not under water when the fan was formed.

7. Later, but probably while the ice-front still lay in the same position, the level of glacier-lake Ennerdale was raised to 800 ft., and the lake spread over the foot of the fells to the north as far as Lamplugh. The ice-cap still covered the fells but had disappeared from Lower Ennerdale, possibly owing to flotation of its ice as bergs by the lake-water.

8. The cause of the rise of the lake-level from 600 ft. to 800 ft. was a readvance of the Irish Sea ice, which closed the outlet of the lake at the lower level.

9. This readvance may or may not have been due to relief from the counter-pressure of the Lake District ice-cap.

10. Still later the lake-level fell by stages to 600 ft. again. Presumably renewed retreat of the Irish Sea ice disclosed lower outlets down to that formerly used.

11. The most obvious deposits in the glacier-lake are the deltas of glacier-fed streams.

12. Ennerdale Water is presumably dammed by the Drift, apparently a terminal moraine, deposited by a lobe of Irish Sea ice upon its readvance.

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APPENDIX II

List of Fossil Plants from the Upper Carboniferous Rocks of the Northumberland and Durham Coalfield and their bearing on the Age of the Coalfield.

By R. Kidston, LL.D., D.Sc., F.R.S.

Less is known of the fossil plants and their distribution in the Northumberland and Durham Coalfield than in any of the other important British Coalfields. From many of the Coal Seams not a single fossil plant is recorded and no systematic collecting of these fossils has ever, except at one or two localities, been undertaken. Sufficient plant evidence has however been obtained to enable one to determine definitely the age of the greater portion of the coal-bearing strata, and the only region where any doubt as to this exists is restricted to the rocks associated with the *Brockwell Seam* and the Upper Carboniferous strata lying below it.

Some fossil plants from the highest visible beds in the Coalfield at Claxheugh on the Wear, about 2 miles west of Sunderland, which were submitted to me for examination by Dr. C. T. Trechmann (*Trechmann and Woolacott. On the Highest Coal-Measures or Zone of Anthracomya Phillipsi in the Durham Coalfield. Geol. Mag., Dec. vi., vol. vi., p.* 203, 1919.) contained the following species :—

Neuropteris gigantea Sternb.
Calamites Suckowi Brongt.
Lepidodendron simile Kidston.
Lepidophyllum triangulare Zeiller.
Sigillaria discophora König sp.

These are all species common in the Westphalian Series and although most occur in the basal group (Blackband Group) of the Staffordian Series the plant evidence justifies the beds from which they were derived being included in the Westphalian Series. From these beds then, down to and including the *Three-quarter Seam* which lies a little above the *Brockwell Seam*, the whole Series is of Westphalian age.

From the Brockwell Seam I have only seen the following few plants :—

Neuropteris rectinervis Kidston.
Calamites Schützeiformis K. and J. *forma Waldenburgensis* Kidston pro. sp.
Palaeostachya Ettingshauseni Kidston.
Lepidodendron aculeatum Sternb.
,, *simile* Kidston.
Stigmaria ficoides Sternb. sp.
Trigonocarpus amygdalæformis Göpp. and Berger.

These all occur both in the Lanarkian and Westphalian Series. The absence however of any species characteristic of

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Westphalian rocks and the fact that fossil plants are so scarce on the Brockwell horizon point to a Lanarkian age for the beds. For these reasons, it appears most probable that the Brockwell Seam and the underlying Upper Carboniferous Rocks are of Lanarkian age and as such they are here provisionally classed.

I wish to express my indebtedness for help to the following friends who have most kindly allowed me to examine their collections and to whom my knowledge of the fossil plants of the Northumberland and Durham Coalfield is almost entirely due. To Mr. J. Sim, Cramlington, Mr. J. T. Stobbs, F.G.S., Dr. C. T. Trechmann, F.G.S., Mr. P. Charlton, Ebchester, and especially to Mr. W. Eltringham, Ryton, who has added many new records to the Fossil Flora of the Coalfield. To Prof. Hickling I am indebted for allowing me to examine the Hutton Specimens under his charge in the Armstrong College. I also take this opportunity of acknowledging much kind help received from Mr. E. Leonard Gill, M.Sc., Curator of the Hancock Museum, Newcastle-on-Tyne, during my visits to the Museum.

After the localities in the following list, the name of the Collector to whom I am indebted for the record or the Museum in which the specimen is contained, is indicated by the letters mentioned below.

E. = W. Eltringham; J. S. = J. Sim; T. = C. T. Trechmann; S. = J. T. Stobbs; C. = P. Charlton; H. = Hancock Museum, Newcastle-on-Tyne; H. A. = Hutton Collection, Armstrong College, Newcastle-on-Tyne. B.M. = British Museum.

List of Species.

Westphalian Series.

Fern and Fern-like Plants.

Sphenopteris

obtusiloba Brongt.

Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Backworth Colliery, 6½ miles N.E. of Newcastle. (E.)

Durham. *Horizon* :—Bensham Seam. *Localities* :—Bensham Colliery, Bensham; Jarrow Colliery, Jarrow. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Six-quarter Seam. *Locality* :—Elizabeth Pit, Tanfield Lea. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

dilatata L. and H.

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy's Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)

Sauveuri Crépin.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

nummularia Gutbier.

Durham. *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

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Schillingsi Andrae.
Northumberland. *Horizon* :— ? . *Locality* :—Gosforth, near Newcastle (T.).

Laurenti Andrae.
Durham. *Horizon* : — Six-quarter Seam. *Locality* : — Stargate Colliery, Ryton. (E.)

rotundifolia Andrae.
Durham. *Horizon* :—Five-quarter Seam. *Locality* :—West Thornley Colliery, Tow Law. (S.)

spiniformis Kidston.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

pseudo-furcata Kidston.
(*Sphenopteris furcata* L. and H. (*non* Brongt.) Fossil Flora. pl. clxxxi.)
Durham. *Horizon* : –Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

Footneri Marrat.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

bella Stur sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Six-quarter Coal. *Locality* :—Tanfield Lea Colliery, Tanfield. (E.)

Schatzlarensis Stur (*pars.*)
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Five-quarter Seam. *Locality*:—West Thornley Colliery, Tow Law. (S.)

Schwerini Stur sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Vernoni Kidston ms.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

RHODEA

Eltringhami Kidston ms.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

DIPLOTMEMA

furcatum Brongt.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J. S.) *Horizon* :—Three-quarter Seam. *Locality* :—Heddon Colliery, 8 miles N.W. of Newcastle-on-Tyne. (E.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

intermedium Ett. sp.
Durham. *Horizon* :—Six-quarter Coal. *Locality* :—Home Colliery Townley, Ryton. (E.)

Sturi Gothan sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

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RENAULTIA

gracilis Brongt. sp.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

URNATOPTERIS

tenella Brongt. sp.

Northumberland. *Horizon* :—High Main Seam. *Locality* :—Gosforth. (H.)

Durham. *Horizon* :—Either Stone Coal or Under five-quarter Seam. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

CROSSOTHECA

Höninghausi Brongt. sp.

Durham. *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (E.)

DACTYLOTHECA

plumosa Artis sp.

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—High Main Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

ZEILLERIA

delicatula Sternb. sp.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Avoldensis Stur sp.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

EREMOPTERIS

artemisiæfolia Sternb.

Northumberland. *Horizon* :—High Main Seam. *Localities* :—Gosforth. (H.) Fawdon, 3 miles N.W. of Newcastle. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (S.).

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Maudlin Seam. *Locality* :—Springwell Colliery, Springwell, 3 miles S.E. of Gateshead. (S.). *Horizon* :—Stone Coal. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.)

ADIANTITES

adiantoides L. and H. sp.

Northumberland. *Horizon* :— ? . *Locality* :—Gosforth, near Newcastle. (H. A.)

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow (H.)

PECOPTERIS

Miltoni Artis sp.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

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MARIOPTERIS

muricata Schl. sp.

Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (S.) *Horizon* :—Yard Coal. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :— Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Five-quarter Seam. *Locality* :—West Thornley Colliery, Tow Law. (S.) *Horizon* :—High Main Seam. *Locality* :—Felling Colliery, Felling. *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Six-quarter Seam. *Locality* :—Elizabeth Pit, Tanfield Lea. (E.) *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Under Five-quarter Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

latifolia Brongt. sp.

Durham. *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

Loshi Brongt. sp.

Locality :—'Mines of Newcastle.' Brongniart. (Type of species.)

Beneckei Huth.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

ALETHOPTERIS

lonchitica Schl. sp.

Northumberland. *Horizon* :—Yard Seam. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth (H.)

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Six-quarter Seam. *Locality* :—Elizabeth Pit, Tanfield Lea, Tanfield. (E.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

decurrens Artis sp.

Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (S.) *Horizon* :—Yard Seam. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :— Crow Coal. *Locality* :— Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—High Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.)

cf. *Serli* Brongt.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

valida Boulay.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

DOLEROPHYLLUM

pseudopeltatum Grand Eury.

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (Type of *Cyclopteris obliqua* L. and H. pl. xc. A. and B. (No. 136a), (No. 137a), (H.)). *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (Type of *Cyclopteris dilatata* L. and H. pl. xci B, (No. 123a), (H.)).

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Dolerophyllum sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

NEUROPTERIS

heterophylla Brongt.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (S.) *Horizon* :—Yard Seam. *Locality* :—Shiremoor, 3½ miles N.W. of Tynemouth
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Six-quarter Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

tenuifolia Schl. sp.
Durham. *Horizon* :—'Not far below the Permian.' *Locality* :—Blackhall Colliery Sinking, Claxheugh. (T.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy's Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)

forma major Kidston ms.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

rectinervis Kidston.
Northumberland. *Horizon* :—Three-quarter Seam. *Locality* :—Horsley Drift, Horsley. (E.)
Durham. *Horizon* :—Under Five-quarter Seam. *Locality* :—Elizabeth Pit, Tanfield Lea, Tanfield. (E.) *Horizon* :—Six-quarter Seam. *Locality* :—Tanfield Lea Colliery, Tanfield. (E.) *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

thymifolia Sternberg.
Durham. *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) (*N. Soretii* L. and H. pl. l.).

Missouriensis White.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Grangeri Brongt.
Durham. *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

obliqua Brongt. sp.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy's Hedley Fell Drift, 1 mile N. of Chopwell. (E.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) (*forma impar*). *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H. A.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

Rytoniana Kidston ms.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

formosa Kidston ms.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Eltringhami Kidston ms.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

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Jongmansi Kidston ms.
Durham. *Horizon* :—Six-quarter Seam. *Locality* :—Elizabeth Pit. Tanfield Lea, Tanfield. (E.)

Osmundæ Artis sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Scheuchzeri Hoffm.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

gigantea Sternb.
Northumberland. *Horizon* :—Hutton Seam (Low Main). *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. (E.) *Horizon* :—Yard Coal. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.C.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

APHLEBIA
anomala Brongt. sp
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

Lebouri Kidston.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (Rhacophyllum ? Lebour. Illustr. Fos. Plants. pls. xlii—xliii, 1877.) (H.)

SPIROPTERIS
Spiropteris sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

MEGAPHYTON
frondosum Artis.
Durham. *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling.

approximatum L. and H.
Durham. *Horizon* :—High Main Seam. *Locality* :—Jarrow Colliery, Jarrow.

Gwynne-Vaughani Kidston ms.
Durham. *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.)

Ossimi Kidston ms.
Durham. *Horizon* :— ? . *Locality* :—Etherley. (H.)

AULACOPTERIS
vulgaris Grand Eury.
Durham. *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

EQUISETALES.

CALAMITES
undulatus Sternb.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Wedekindi Weiss.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

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semicircularis Weiss.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.A.)

Goepperti Ett.
Durham. *Horizon* :— ? . *Locality* :—Land's Pit, near Etherley,

Sachsei Stur.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.)

Schützeiformis Kidst. and Jong. *forma typicus* K. and J.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) (*C. approximatus* L. and H. pl. lxxvii.)

Schutzeiformis forma Waldenburgensis Kidst. pro spec.
Northumberland. *Horizon* :—Low Main Coal. *Locality* :—Cramlington. (J. S.)

Suckowi Brongt.
Northumberland. *Horizon* :—Low Main Coal. *Locality* :—Cramlington.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Five-quarter Seam. *Locality* :—West Thornley Colliery, Tow Law. (S.) *Horizon* :—Six-quarter Coal. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Stone Coal. *Localities* :—Emma Colliery, 1 mile S.W. of Ryton. Townley Pit, Ryton (E.). *Horizon* :—Under five-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

Cisti Brongt.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.) *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J.S.)
Durham. *Horizon* :—Six-quarter Coal. *Localities* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) Stargate Colliery, Ryton. (E.)

jubatus L. and H.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Under five-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester.

carinatus Sternb.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling.

paleaceus Stur.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

ASTEROPHYLLITES

equisetiformis Schl. sp.
Northumberland. *Horizon* :—High Main Seam. *Locality* :—Gosforth. (H.) *Horizon* :—Five-quarter Seam *Locality* :—West Wylam Colliery, 2 miles W. of Ryton. (E.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Under Five-quarter

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Seam. *Localities* :—Townley Pit, Ryton. (E.) West Thornley Colliery, Tow Law. (S.) *Horizon* :—Main Coal. *Locality* :—Pelton Colliery, Pelton, 2 miles N.W. of Chester-le-Street. (E.) *Horizon* :—Six-quarter Seam. *Localities* :—Elizabeth Pit, Tanfield Lea Colliery, Tanfield. (E.) Stargate Colliery, Ryton. (E.) *Horizon* :—Stone Coal. *Localities* :—Townley Pit, Ryton. (E.) Emma Colliery, 1 mile S.W. of Ryton. (E.) Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Under Five-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

longifolius Sternb. sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

grandis Sternb. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H. A.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Six-quarter Seam. *Locality* :—Stargate Colliery, Ryton. (E.)

Huttoni Lebour.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow.

charaeformis Sternb. sp.
Northumberland. *Horizon* :— ? . *Locality* :—Gosforth, near Newcastle. (H.A.)
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—" One of four seams above Brockwell Coal." *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (E.)

ANNULARIA

radiata Brongt.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J. S.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Five-quarter Seam. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (E.)

dubia Sternb. sp.
Northumberland. *Horizon* :—High Main Seam. *Locality* :—Hazelrigg, Gosforth. (H.)
Durham. *Horizon* :—Six-quarter Coal. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Stone Coal. *Localities* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.) Stargate Colliery, Ryton. (E.) *Horizon* :—Three-quarter Coal. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.)

ramosa Weiss.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

galioides L. and H.
Northumberland. *Horizon* :— ? . *Locality* :—Gosforth, near Newcastle. (T.)
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

microphylla Sauveur.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Main Coal. *Locality* :—Pelton Colliery, 2 miles N.W. of Chester-le-Street. (E.)

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CALAMOSTACHYS

paniculata Weiss.
Durham. *Horizon* :—Stone Coal. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Under five-quarter Seam. *Locality* :—Elizabeth Pit, Tanfield Lea, Tanfield. (E.)

Northumbriana Kidston. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling. (B. M.)

PALAEOSTACHYA

elongata Presl sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

gracillima Weiss.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Ettingshauseni Kidston.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

MYRIOPHYLLITES

gracilis Artis.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H. A.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Seam *Locality* :—Felling Colliery, Felling. (H.)

SPHENOPHYLLALES.

SPHENOPHYLLUM

cuneifolium Sternb. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Six-quarter Seam. *Localities* :—Stargate Colliery, Ryton. (E.) Elizabeth Pit, Tanfield Lea, Tanfield. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

forma amplum Kidston.
Durham. *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

trichomatosum Stur.
Durham. *Horizon* :—Main Coal. *Locality* :—Pelton Colliery, Pelton, 2 miles N.W. of Chester-le-Street. (E.)

LYCOPODIALES.

LEPIDODENDRON

ophiurus Brongt.
Northumberland. *Horizon* :—Beaumont Seam. *Locality* :—Shiremoor Colliery, Shiremoor, 3½ miles N.W. of Tynemouth. (E.) *Horizon* :—Bensham Seam. *Locality* :—Shiremoor Colliery, Shiremoor, 3½ miles N.W. of Tynemouth. (H.) *Horizon* :—Yard Coal. *Locality* :—Shiremoor Colliery. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Brass Thill. *Locality* :—Drift at Tanfield Village, near Stanley. (E.) *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling. *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.) *Horizon* :—Under Five-quarter Seam. *Locality* :—Emma (Townley) Colliery, 1 mile S.W. of Ryton. (E.)

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dichotomum Zeiller. (Sternb. ?)
Durham. *Horizon* :—Main Coal. *Locality* :—Pelton Colliery, Pelton, 2 miles N.W. of Chester-le-Street. (E.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

aculeatum Sternb.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J. S.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow (H.). *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Five-quarter Coal. *Localities* :—Greenside Colliery, 1 mile S. of Ryton. (E.) West Thornley Colliery, Tow Law. (S.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Townley Seam. *Locality* :—West Wylam Colliery, 2 miles W. of Ryton. (E.) *Horizon* :—Three-quarter Seam—Yard Coal. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.)

serpentigerum König.
'Newcastle-on-Tyne Coalfield.' (B. M.)

obovatum Sternb.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Walter Colliery, between Byker and Wallsend. (S.) *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J.S.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Brass Thill. *Locality* :—Drift at Tanfield Village near Stanley. (E.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Main Coal. *Locality* :—Pelton Colliery, Pelton, 2 miles N.W. of Chester-le-Street. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Six-quarter Coal. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Tilley Seam. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—West Wylam Colliery, 2 miles W. of Ryton. (E.)

Peachi Kidston.
Northumberland *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J.S.) *Horizon* :—Low Main Seam. *Locality* :—Newsham, Durham. *Horizon* :—Brass Thill Seam. *Locality* :—Tanfield Colliery, Tanfield Lea, Tanfield. (E.)

acutum Presl sp.
Durham. *Horizon* :—Stone Coal. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.)

simile Kidston.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Shiremoor, 3½ miles N.W. of Tynemouth. (H.) *Horizon* :—Hutton Seam. *Locality* :—Mickley Colliery Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)
Durham. *Horizon* :—Brass Thill. *Locality* :—Drift at Tanfield Village, near Stanley. (E.) *Horizon* :—Hutton Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Six-quarter Coal. *Localities* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) Stargate Colliery, Ryton. (E.) Elizabeth Pit, Tanfield Lea, Tanfield. (E.) Townley Colliery, Ryton. (E.) *Horizon* :—Three-quarter Coal. *Locality* :—Emma Colliery, Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton.

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Wortheni Lesqx.
Northumberland. *Horizon* :—Main Coal. *Locality*:—Dinnington Colliery, 6 miles N. of Newcastle-on-Tyne. (E.)

fusiforme Corda.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Townley Pit, Ryton. (E.).

LEPIDOSTROBUS.

lanceolatum L. and H.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Six-quarter Seam. *Localities* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) Elizabeth Pit, Tanfield Lea, Tanfield. (E.) Stargate Colliery, Ryton. (E.)

Jacksoni Arber.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow. (H. A.)

spinosus Kidston.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow. (H.)

variabilis L. and H
Durham. Bensham Seam. *Localities* :—Walker Colliery, 6 miles E. of Newcastle-on-Tyne. (S.) Jarrow Colliery, Jarrow. (H.)

LEPIDOPHYLLUM

majus Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

acuminatum Lesqx.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow.

triangulare Zeiller.
Durham. *Horizon* :—A very few fms. above Main Seam. *Locality* :—Pelaw Brick Yard, Pelaw, 3 miles, E.S.E. of Gateshead. (E.)

LEPIDOPHLOIOS

laricinus Sternb.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—A few fms. above High Main Seam. *Locality* :—Pelaw Brick Yard, Pelaw, 3 miles E.S.E. of Gateshead. (R.) *Horizon* :—Six-quarter Coal. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

acerosus. L. and H. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—A very few fms. above High Main Seam. *Locality* :—Pelaw Brick Yard, Pelaw, 3 miles E.S.E. of Gateshead. (E.) *Horizon* :—High Main Seam. *Locality* :—South Shields. *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

HALONIA

tortuosa L. and H.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—West Wylam Colliery, 2 miles W. of Ryton. (E.)

KNORRIA.

Selloni L. and H. (*non* Sternb ?)
Durham. *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling.

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Bothrodendron

punctatum L. and H.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—High Main Seam. *Localities* :—Jarrow Colliery, Jarrow. Jarrow Quarry, Jarrow. (*Geol. Survey*, London, No. 5257.)

minutifolium Boulay.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Newsham. (H.)
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. *Horizon* :—Six-quarter Coal. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.)

Asolanus

camptotoenia Wood.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Sigillaria

discophora König. sp.
Northumberland. *Horizon* :—Low Main Coal. *Locality* :—Cramlington. (J. S.) *Horizon* :—Yard Coal. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—High Main Seam. *Locality* :—South Shields.

tessellata Brongt.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

cf. nodosa L. and H. sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

mamillaris Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

scutellata Brongt.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley, 1 mile N. of Chopwell. (E.) *Horizon* :—Main Coal. *Locality* :—Seaton Delaval Colliery, 3 miles S.W. of Blyth. (E.)
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

vulgaris Artis sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Boblayi Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Tilley Seam. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.)

rugosa Brongt.
Northumberland. *Horizon* :—Main Coal. *Locality* :—Seaton Delaval Colliery, 3 miles S.W. of Blyth. (E.)

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elongata Brongt.
Durham. *Horizon* :—Six-quarter Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

orbicularis Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

laevigata Brongt.
Northumberland. *Horizon* :—Hutton Coal. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

reniformis Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Pringlei Kidston.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Hedley Fell Drift, 1 mile N. of Chopwell. (E.)

coriacea Kidston.
'Newcastle-on-Tyne Coal Field.' (B.M.)

cf. peltata Sauveur.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

ovata Sauveur.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. *Horizon* :—Main Coal. *Locality* :—Seaton Delaval Colliery, 3 miles S.W. of Blyth.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon*:—Townley Seam. *Locality*:—Spen Colliery, 3 miles S. of Ryton. (E.) *Horizon* :—Under five-quarter Seam. *Localities* :—Townley Colliery, Ryton. (E.) Clara Vale Colliery near Ryton. (E.)

ovalis Lesqx.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J. S.)
Durham. *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

Schlotheimiana Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

euxina Zeiller.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)

Sauveuri Zeiller.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Davreuxi Brongt.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)

cordiformis Kidston.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Hedley Drift, 1 mile N. of Chopwell. (E.)
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

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scutiformis Zalessky.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

transversalis Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

diploderma Corda.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

SIGILLARIOPHYLLUM

bicarinatum L. and H. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H. A.)

STIGMARIA

ficoides Sternb. sp.
Generally distributed in the Coalfield.

minuta Göpp. *pro var.*
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Six-quarter Seam. *Locality* :—Clara Vale, near Ryton. (E.)

reticulata Göpp. *pro var.*
Durham. *Horizon* :—Six-quarter Seam. *Locality* :—Clara Vale, near Ryton. (E.)

STIGMARIOPSIS

anglica Kidston.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

CORDAITALES.

CORDAITES

principalis Gemar sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

borassifolius Sternb. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H. A.)

CORDAIANTHUS

Pitcairniae L. and H. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Five-quarter Coal. *Locality* :—West Thornley Colliery, Tow Law. (S.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling.

pseudofluitans Kidston.

Samaropsis fluitans Weiss (*non* Dawson) Foss. Flora jüngst. Steink. u.d. Rothl. p 209, pl. xviii, figs. 24–30, 1869.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.)

Volkmanni Ett. sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

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CORDAICLADUS

taxinus L. and H. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

ARTISIA

approximata Brongt. sp.
Durham. *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—18 fms. from surface. *Locality* :—No. 3 Pit, Chopwell, 2½ miles N.E. of Ebchester. (C.)

transversa Artis sp.
Durham. *Horizon* :—18 fms. from surface. *Locality* :—No. 3 Pit, Chopwell, 2½ miles N.E. of Ebchester. (C.)

SEEDS.

SAMAROPSIS

acuta L. and H. sp.
Northumberland. *Horizon* :— ? . *Locality* :—Gosforth, near Newcastle-on-Tyne. (H. A.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow.

POLYPTEROSPERMUM

ornatum Arber sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

TRIGONOCARPUS

Parkinsoni Brongt.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—18 fms. from surface. *Locality* :—No. 3 Pit, Chopwell, 2½ miles N.E. of Ebchester. (C.)

Noeggerathi Sternb. sp.
Durham. *Horizon* :—18 fms. from surface. *Locality* :—No. 3 Pit, Chopwell, 2½ miles N.E. of Ebchester. (C.)

CARDIOCARPUS

congruens Grand 'Eury sp.
Durham. *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

CARPOLITHUS

perpusillus Lesqx.
Durham. *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Three-quarter Seam. *Locality*.—Chopwell, 2½ miles N.E. of Ebchester. (C.)

ellipticus Sternb.
Durham. *Horizon* :—Under Five-quarter Seam. *Locality* :—Clara Vale Colliery, near Ryton. (E.)

sp.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Hedley Drift, 1 mile N. of Chopwell. (E.)

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MEGALOSPERUM

inflatum Lesqx. sp.
Durham. *Horizon* :—Six-quarter Seam. *Locality* :—Tanfield Lea Colliery, Tanfield. (E.)

GENERA OF UNCERTAIN POSITION.

PSYGMOPHYLLUM

flabellatum L. and H. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow.

DICRANOPHYLLUM.

sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

ROOTS.

PINNULARIA

columnaris Artis sp.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling.

capillacea L. and H.
Horizon :—Yard Seam. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)

? LANARKIAN SERIES.

Durham. *Horizon* :—Brockwell Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

Neuropteris rectinervis Kidston.

Palaeostachya Ettingshauseni Kidston.

Lepidodendron aculeatum Sternb.

,, *simile* Kidston.

Stigmaria ficoides Sternb.

Trigonocarpus amygdalæformis Göpp. and Berger sp.
Horizon :—Brockwell Seam. *Locality* :—Greenside Colliery, 1 mile S. of Ryton. (E.)

Calamites Schützeiformis forma Waldenburgensis Kidston pro sp.

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APPENDIX III

On a Boring for Coal at Westbury, Wiltshire

By J. Pringle.

Early in the year 1914 boring commenced on a site slightly over 200 feet above Ordnance Datum in the grounds of the New Westbury Iron Company's works,[1] which are situated alongside the railway at Westbury Station; and through the courtesy of the manager, Mr. W. J. Love, sanction was given to the Geological Survey in March 1915 to examine the cores at the borehole. Several visits were made until August of the same year when the boring was stopped, and we are indebted to the Directors of the Company for their permission to publish this account. We have also to thank Mr. Love for his valuable assistance during the examination of the cores, and for placing the information contained in the log of the boring at our disposal.

The details of the strata passed through are set forth on the table below. They are based on a personal examination of the cores, which varied from four inches to one inch in diameter. Excepting certain portions of the Inferior Oolite, there was shown a fairly complete sequence of the local Jurassic rocks. Each formation present appeared to exhibit similar lithological characters to those of the corresponding beds outcropping in Somerset and Wiltshire. The boring revealed the existence of a marked break in the sequence of Liassic deposits, proving the absence of the whole of the Middle Lias and the greater part of the Upper Lias. The discovery of Coal Measures at a depth of 1,326 feet below Ordnance Datum is of importance, and although the precise horizon of the beds within the formation remains undetermined, further borings in the area would be justified. It is of interest to note that the first suggestion of the possibility of Coal Measures occurring under the Trias at Westbury was made by W. H. Bell in 1890.[2]

Section of the Jurassic and Carboniferous rocks in the Westbury borehole.

		Thickness. Ft.	in.	Depth. Ft.	in.
	Brown surface soil	8	0	—	
Corallian, 78¾ ft.	Iron ore, sandy at base	4	10	—	
	Whitish-grey coarsely pisolitic limestone	4	0		
	Grey finely oolitic limestone with patches of dark clay	24	10		
	Dark greasy clay, oolitic grains at base	9	0		
	Brownish-black clay	7	0		
	Light brown shelly clay	6	0		
	Brownish-black clay, somewhat sandy at top	17	9		
	Hard brownish-grey calcareous sandstone	5	4	86	9

[1] New Series 1-inch Ordnance Map, Sheet 281; 6-inch map Wiltshire 44 N.E.; Old Series 1-inch Geological Map 14.

[2] W. H. Bell. 'The Buried Palaeozoic Rocks of Wiltshire.' *Wilts. Arch. and Nat. Hist. Mag.*, vol. xxv, 1891, pp. 80—85.

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		Thickness. Ft.	in.	Depth. Ft.	in.
Oxford Clay, 527½ ft.	Grey shelly clay with numerous brown filaments. *Quenstedtoceras* near base	16	0		
	Pale smooth limy clay with septarian nodules	20	0		
	Grey and brownish-grey clays, shelly in places with numerous nodules in upper half. *Quenstedtoceras* spp. plentiful. Some gaps in core-sequence	351	3		
	Soft dark brown greasy clay with *Cosmoceras gulielmi* J. Sow., *Pseudomonotis sp. nov.* &c.	140	0	614	0
Kellaways Rock, 7½ ft.	Greenish-grey sandy calcareous clay with numerous specimens of *Pseudomonotis sp. nov.*, and *Gryphaea sp.*	72	3	686	3
Cornbrash, 8¾ ft.	Dark grey limy clay	2	3		
	Hard grey sandy limestone with *Macrocephalites sp.*	6	6	695	0
Forest Marble, 91 ft.	Pale whitish earthy limestone with bluish-grey shelly patches, sparsely oolitic	3	0		
	Dark grey shelly clay	1	0		
	Smooth compact greenish clay with plant fragments	11	0		
	Light grey limy clay	12	0		
	Greyish-white sandy limestone with thin bands of bluish-grey limestone	9	6		
	Whitish-grey limy clay	54	0		
	Dark bluish-grey oolitic limestone		6	786	0
Great Oolite (Fullonian facies), 207½ ft.	Upper Fullers Earth, 146 ft. — Smooth black and greyish-white clays with *Ostrea sp.* and *Rhynchonella varians* (Schloth.), var. *smithi* Walker	141	0		
	Upper Fullers Earth, 146 ft. — Whitish-grey limestone with a thin clay parting	4	0		
	Upper Fullers Earth, 146 ft. — Soft dark-grey shelly clay	1	0	932	0
	Fullers Earth Rock, 21½ ft. — Hard whitish-grey limestone with thin grey marly bands	21	6	953	6
	Lower Fullers Earth, 40 ft. — Whitish-grey limy clay with thin bands of limestone near base	40	0	993	6
Inferior Oolite, 128½ ft.	Hard fine grained oolite with a thin layer of *Ostrea* shells at top. At 994 ft. limestone is full of worm-borings, and between 1,000 and 1,010 ft. coarsely oolitic beds contain *Anabacia*; cores incomplete	43	6	1,037	0
	No core between 1,037 ft and 1,061 ft.	24	0		
	Brownish-grey sandy limestone. 3 inches of core seen at 1,061 ft. No core between 1,061¼ ft. and about 1,122 ft. Hard grey limestone with Ammonites, 3 inches seen at 1,122 ft.	61	0	1,122	0
	Upper — Soft dark muddy sandstone with two thin bands of sandy limestone. Ammonites at 1,134 ft.	12	0		

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			Thickness. Ft.	in.	Depth. Ft.	in.
Lias, 174½ ft.	Lias, 48 ft.	No core between 1,134 ft. and 1,152 ft.	18	0		
		Soft dark sandy clay with two thin calcareous bands	18	0	1,170	0
		Unconformity.				
	Lower Lias, 126½ ft.	Bluish-grey micaceous clay	82	0		
		Hard grey earthy limestones with marly bands	3	6		
		Dark brown shelly clay with thin band of limestone	3	0		
		Hard whitish-grey limestone with clay bands	24	6		
		Bluish-grey clay with thin bands of grey limestone	9	9		
		Hard whitish-grey limestone with thin beds of grey marl	3	2		
		Dark shaly clay		10	1,296	9
Rhaetic, 43 ft. 8 in.		Smooth white and greyish-white limestones with a thin bed of dark clay. (White Lias)	27	3		
		Black shales with a thin band of dark limestone. (*P. contorta* shales).	16	5	1,340	5
Keuper, 185 ft. 7 in.		Smooth pale greenish marl	8	3		
		Dark red marl	4	0		
		Pale blotchy greenish marl	3	0		
		Red marls veined in places with thin bands of gypsum. A narrow band of greyish-white breccia occurs at 1,473 feet	169	4		
		Whitish compact limestone with pebbles of red quartzite	1	0	1,526	0
		Unconformity.				
Coal Measures, 125½ ft.		Red stained fine grained micaceous sandstones	36	0		
		Grey micaceous sandstone with plant fragments	8	0		
		Grey sandy shale	37	5		
		Hard grey quartzose sandstone and grey micaceous sandstone. Red stained along joint-planes	12	7		
		Grey shales with ironstone nodules. *Calamites* and *Stigmarian* rootlets	31	6	1,651	6
		Bottom of boring.				

Notes on the formations passed through in the borehole.

Corallian.—The boring was commenced near the base of the well-known seam of iron-ore which forms the uppermost member of the Corallian rocks in the neighbourhood of Westbury. The details of the formation, as exhibited in the cores, do not differ materially from the description of the beds passed through in the iron-work's well as given by Mr. Greenwell,[1] and thus do not call for special mention. The base of the Corallian was taken at the

[1] *See* H. B. Woodward. 'The Jurassic Rocks of Britain' (*Mem. Geol. Surv.*), vol. v., 1895, p. 111.

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depth of 86 feet 9 inches, thus including a bed of brownish-grey calcareous sandstone which appears to correspond to the band of rock overlying the Oxford Clay at the bottom of the ironwork's well. Fossils were somewhat rare in the limestones, but the following shells were found in the clays :—*Modiola bipartita* J. Sow., *Ostrea* (*Alectryonia*) *gregaria* J. Sow., *Pecten* (*Chlamys*) *fibrosus* J. Sow., *P.* (*Camptonectes*) *lens* J. Sow., *Pleuromya recurva* ? Phill., and a clavellate species of *Trigonia*.

Oxford Clay.—By 1915, a considerable portion of the clay-cores had broken down owing to weathering, and consequently it was not possible to collect specimens with accuracy with regard to depths between 90 and 474 feet from the surface. Viewed broadly, this formation falls in this boring into two lithological divisions of unequal thickness. The upper part, which is 387 feet thick, consists principally of pale grey marly clays with some darker bands and occasional layers of septarian nodules. The clays are characterised by the presence of numerous specimens of *Quenstedtoceras*, one of which was found about 16 feet from the top of the subdivision, and it is highly probable that both the Mariae and Renggeri Zones are present in their full development, although the limits of each zone could not be determined. The following fossils were obtained :—*Nuculana sp.*, *Ostrea sp.*, *Pecten* (*Chlamys*) *fibrosus* J. Sow., *Pinna mitis*, Phill., *Pleuromya recurva* ? Phill., *Pteria* (*Oxytoma*) *inaequivalvis* (J. Sow.), *Cerithium sp.*, *Quenstedtoceras* cf. *macrum* (Quenst.), *Quenstedtoceras* cf. *lamberti* (J. Sow.) and *Quenstedtoceras sp.*

The lower division is formed by a brown marly clay, 140 feet thick, containing abundant and well-preserved specimens of *Cosmoceras*, which almost rival in beauty the specimens from the same beds in the now inaccessible sections in the railway-cuttings near Christian Malford. The whole of the clay is referred to the Ornatum Zone, and in its lithological characters, the deposit agrees closely with the beds in the same zone passed through in the Kentish borings, where also the brownish hue of the clays is a highly characteristic feature. The following fossils were collected :—

	Depth in feet.
Serpula vertebralis *J. de C. Sow.*	499, 520
Nucula *cf.* oxfordiana *Roeder*	557
Nuculana phillipsi *Morris*	499, 614
Pinna mitis *Phill.*	594
Pseudomonotis sp. nov.	546–557
Cerithium sp.	,,
Cosmoceras gulielmi (*J. Sow.*)	590, 594, 598–602
,, jason *Rein.*	499
Cf. Siemiradzkia bakeriae (*J. de C. Sow.*)	,,

Kellaways Rock.—The greenish-grey sandy calcareous clay closely resembles the beds referred to the Kellaways Rock in the Swindon boring,[1] where it appears to be slightly thinner.

[1] H. B. Woodward. 'Account of a well sinking made by the Great Western Railway Company at Swindon,' *Quart. Journ. Geol. Soc.*, vol. xlii., 1886, p. 287.

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Fossils occurred frequently throughout, and a list of the forms obtained is as follows:—*Serpula sp.*, *Astarte carinata*? Phill., *Grammatodon montaneyensis* (de Lor.), *Gryphaea sp.*, *Lucina rotundata* Roem., *Modiola bipartita* J. Sow., *Ostrea sp.*, *Pecten* (*Syncyclonema*) *demissus* Phill., *Pseudomonotis sp. nov.*, *Trigonia sp.* (clavellate), *Cerithium sp.*, and at the depth of 666 feet *Proplanulites* cf. *koenigi* (J. Sow.). The *Pseudomonotis sp. nov.* is closely related to, if not identical with, a shell from the Kellaways Rock of the shafts and borings in Kent. As pointed out elsewhere,[1] similar shells have been incorrectly referred to *P. ovalis* (Phill.), which is found in the Corallian Rocks. At Westbury, *Pseudomonotis sp. nov.* occurs abundantly in the Kellaways Rock, and ranges upwards into the lower half of the Ornatum Zone of the Oxford Clay.

Cornbrash and Forest Marble.—It was of interest to note that the highest bed of the Cornbrash is identical in aspect and composition with the bed of clay forming the top of the formation in the majority of the boreholes in Kent. At Westbury, it yielded only a few fossils amongst which is a small strongly ribbed *Astarte* referred provisionally to *A. fimbriata* Lycett. In the underlying limestone the following characteristic shells were obtained:—*Pecten* (*Syncyclonema*) *demissus* Phill., *Pseudomonotis echinatus* (J. Sow.), and a large fragment of *Macrocephalites*. The formation appears to be much thinner in the cores than along the outcrops between Trowbridge and Wincanton, where it is estimated to be about 25 feet thick.[2]

The Forest Marble is mainly represented by smooth pale grey clays. They include, however, a thick bed of greyish-white sandy limestone, and several thin bands of bluish-grey oolitic limestone. Near the top some of the clays are of greenish hue, and strongly resemble the lower members of the formation overlying the Great Oolitic limestones in the railway-cuttings near Bicester. Owing to the small size of core, it was difficult to fix the base of the formation, but it was taken at a level where the clays assume a Fullonian hue, so as to include the lowest band of oolitic limestone which is identical in appearance with the numerous thin limestone-bands characterising a level 54 feet higher. Thus assigned, the thickness of the beds is in agreement with the measurements of the sections in the neighbourhood of Frome where the Forest Marble is stated to be about 90 feet thick.[3]

Largely owing to the narrow diameter of the core, few fossils were obtained; these include plant fragments, *Grammatodon sp.*, and *Ostrea sp.*

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[1] G. W. Lamplugh and F. L. Kitchin. 'On the Mesozoic Rocks in some of the Coal Explorations in Kent' (*Mem. Geol. Surv.*), 1911, p. 136.

[2] H. B. Woodward. 'The Jurassic Rocks of Britain' (*Mem. Geol. Surv.*), vol. iv, 1894, p. 439.

[3] H. B. Woodward. 'The Jurassic Rocks of Britain' (*Mem. Geol. Surv.*), vol. iv, 1894, p. 349.

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Great Oolite.—The three subdivisions of Fullers Earth rocks are present. The Upper Fullers Earth Clay, with the exception of two thin greyish-white limestones. consists of grey, greyish-white and black clays, and it closely agrees in thickness with the corresponding beds at Scale Hill, south-east of Batcombe,[1] and in the Stowell borehole.[2] The Fullers Earth Rock also appears in normal development, though yielding no examples of its characteristic fossils, whilst the clay of the Lower Fullers Earth is nearly of the same thickness as that proved at Hemington.[3]

The clays are shelly in places, but most of the fossils occur in a fragmentary condition, and lend no aid in the recognition of the zonal subdivisions. The shells are as follows :—*Rhynchonella varians* (Schloth.), var. *smithi* Walker, *Terebratula* sp., *Astarte sp.*, *Grammatodon sp.*, Lima (*Plagiostoma*) *cardiiformis* (J. Sow.), *Modiola gibbosa* J. Sow., and *Ostrea sp.*

Inferior Oolite.—As already stated, the details of these deposits are incomplete owing to the failure to secure a core while passing through a large part of the formation. Between the depths of 993 feet and 1,037 feet, however, a sufficient amount of core was obtained to allow the recognition of some of the members of the Inferior Oolite present at Hemington.[4] The fossils found in these beds are shown on the table, p. 147. Below the depth of 1,037 feet the formation continues down to 1,122 feet, where a thin band of dark grey limestone yielding fragments of Ammonites was penetrated. The fossils were submitted to Mr. S. S. Buckman, who suggests that they may belong to the Murchisoniae Zone of the Aalenian. The Westbury boring thus differs from the Hemington boring and the sections in the Bath-Doulting district by the presence of the Inferior Oolite deposits of pre-Garantiana date. Saline water commenced to flow when the depth of 1,102 feet was reached.

Lias.—The soft dark muddy sands yielded some fragments of *Dumortieria* at the depth of 1,134 feet from the surface. These shells were identified by Mr. Buckman, who assigns them to the Dumortieria Zone of the Yeovilian. Below this depth, dark sandy clays, 18 feet thick, contained only a few fragments of Ammonites which could not be identified, and it is not known which zone of the Upper Lias rests unconformably on the Lower Lias.

The evidence of the unconformity, however, is complete. The upper beds of the Lower Lias are represented by a bluish-grey micaceous clay, yielding at the depth of 1,176 feet Ammonites

[1] H. T. De la Beche, Memoirs of the Geological Survey, vol. i, 1846. p. 280.

[2] J. Pringle. 'On a boring in the Fullonian and Inferior Oolite at Stowell.' 'Summary of Progress' for 1908 (*Mem. Geol. Surv.*), 1909, p. 83.

[3] T. C. Cantrill and J. Pringle. 'On a boring for coal at Hemington, Somerset.' 'Summary of Progress' for 1913 (*Mem. Geol. Surv.*), 1914, p. 98.

[4] *Op. cit.*, p. 99.

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of the *subplanicosta* or *densinodus* groups. These fossils have also been examined by Mr. Buckman, who refers the clay in which they were found to the base of the Raricostatum Zone. It is certain therefore that the whole of the Middle Lias and probably the whole of the Whitbian deposits are absent. The core-record of the Lower Lias clays and limestones was complete, and proved a thickness of 126 feet. Fossils were comparatively abundant, but, as a rule, they occurred in a fragmentary condition, and the evidence they yielded is not sufficiently definite to determine whether the sequence of zones is complete to the bottom of the formation. The following fossils were obtained :—*Cidaris edwardsi*? Wright, *Rhynchonella sp.*, *Astarte* cf. *camartonensis* Moore, *Gryphaea incurva* J. Sow. *Pecten* (*Syncyclonema*) *liasianus* Nyst., *Pinna sp.*, *Pteria* (*Oxytoma*) *inaequivalvis* (J. Sow.), *Arnioceras*?, and *Schlotheimia*?, and the Ammonites already mentioned.

Rhaetic.—The White Lias retains the characteristic features of the formation displayed at its outcrop, but the core was too narrow to allow a correlation to be made with the subdivisions established by Richardson.[1] The limestones were fossiliferous in places, and yielded *Myophoria postera* Quenst.

When the *Pteria contorta* shales were entered, a reduction in the size of the hole was made, and from this point downwards a core slightly over one-inch in diameter was obtained. So far as could be judged from the limited material, the shales appeared to be highly fossiliferous, and the following forms were obtained :—*Pteria contorta* (Portl.), *Cardium cloacinum* Quenst., *Cardinia*?, *Modiola minima* Moore, and fish scales.

Keuper.—The Tea-green Marls are present, and contain a 4-feet band of dark red marl. They are sharply marked off from the overlying black shales, and pass gradually below into red marl which is veined in places by thin bands of gypsum. A narrow band of greyish-white breccia was passed through at the depth of 1,473 feet, and at the base of the formation is a thin bed of slightly dolomitised limestone with pebbles of red quartzite.

Coal Measures.—When the Palaeozoic rocks were entered at the depth of 1,526 feet from the surface, it was found that the Keuper Marl rests on strata of Coal Measures age. They are represented by a series of fine grained well-bedded micaceous sandstones and grey shales with ironstone nodules, and were penetrated to the depth of 125 feet. The junction was not shown in the core, but the sudden passage from nearly horizontal Keuper beds to highly dipping strata suggests the striking nature of the unconformity. The relationship between the two groups, however, may not be so sharply contrasted as indicated in the cores, as it is believed that the bore was deflected while passing through the basement-bed of the Trias. The highest beds are stained a

[1] L. Richardson. 'The Rhaetic of West, Mid and East Somerset' *Quart. Journ. Geol. Soc.*, vol. lxvii, 1911, p. 1.

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dark red colour down to the depth of 36 feet below the junction with the Keuper Marl. Some of the shales are slickensided, and they strongly resemble fireclays where penetrated by numerous Stigmarian rootlets. No seams of coal were passed through. The sandstones contain numerous plant-fragments, none of which are recognisable, but the grey shales yielded *Calamites sp.*, Stigmarian rootlets, and *Sphenopteris*? These, however, are not sufficient to determine the position of the rocks within the Coal Measures.

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APPENDIX IV

On the Occurrence of Igneous Intrusions in the Trias at Grinshill and Acton Reynald, Shropshire

By R. W. Pocock, B.Sc.

These igneous intrusions were briefly mentioned in last year's 'Summary of Progress.'[1] The following account gives a more detailed description of the occurrence.

Sir Roderick Murchison recorded the discovery of a dyke at Acton Reynald, seven miles north of Shrewsbury.[2]

The part he examined was about four and a half feet wide, cutting through the horizontal beds of sandstone, on which the house is built, from north-west to south-east. He states that, in its course to the south-east, this dyke in passing under the house expands to a width of eight or nine feet and that a second parallel dyke ranges beneath the western part of the house. These, according to his account, are crossed by a third and larger dyke trending E.N.E. to W.S.W., but their point of intersection had already been built over. He regards the two smaller dykes as branches of this larger one.

On the Old Series 1-inch Geological Survey map, Sheet 73 S.W., published in 1855, three short parallel faults are marked running north-west to south-east under the house. The original field map shows these as green lines, possibly intended to represent the dykes.

In the course of the re-survey of the district in 1920, a narrow dyke was observed crossing a ditch half a mile north-west of Clive Hall and a further exposure was found in the bed of a stream about 300 yards to the north-west. The course of the dyke was then traced, by means of surface fragments, from a point just north of Holbrook Farm, in a south-easterly direction to the hill above Acton Reynald, a distance of about 2 miles.

The course of the dyke thus traced is in a direct line with Murchison's two smaller dykes at Acton Reynald. (Fig. 6).

The general trend of the dyke is remarkably uniform in a direction S. 58° E. In its course to the south-east it traverses successively the Keuper Marl, the Waterstones, the Keuper Basement Beds (here represented by the well-known Grinshill Building-stone), the Upper Mottled Sandstone and the Bunter Pebble Beds.

The dyke, averaging only about 18 inches in width, forms no feature at the surface if we except a small rise in the ground where it crosses a field 400 yards south of Hill Farm.

To the north-west of Holbrook Farm the Keuper Marl outcrop is covered by a thick mantle of boulder-clay and the most northerly point at which evidence of the dyke was obtained is

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, p. 26.

[2] *Proc. Geol. Soc.*, vol. ii. 1835, p. 193; 'Silurian System,' 1839, p. 295.

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at the corner of a field 200 yards north of Holbrook Farm, where several fragments of the rock were found. Further fragments

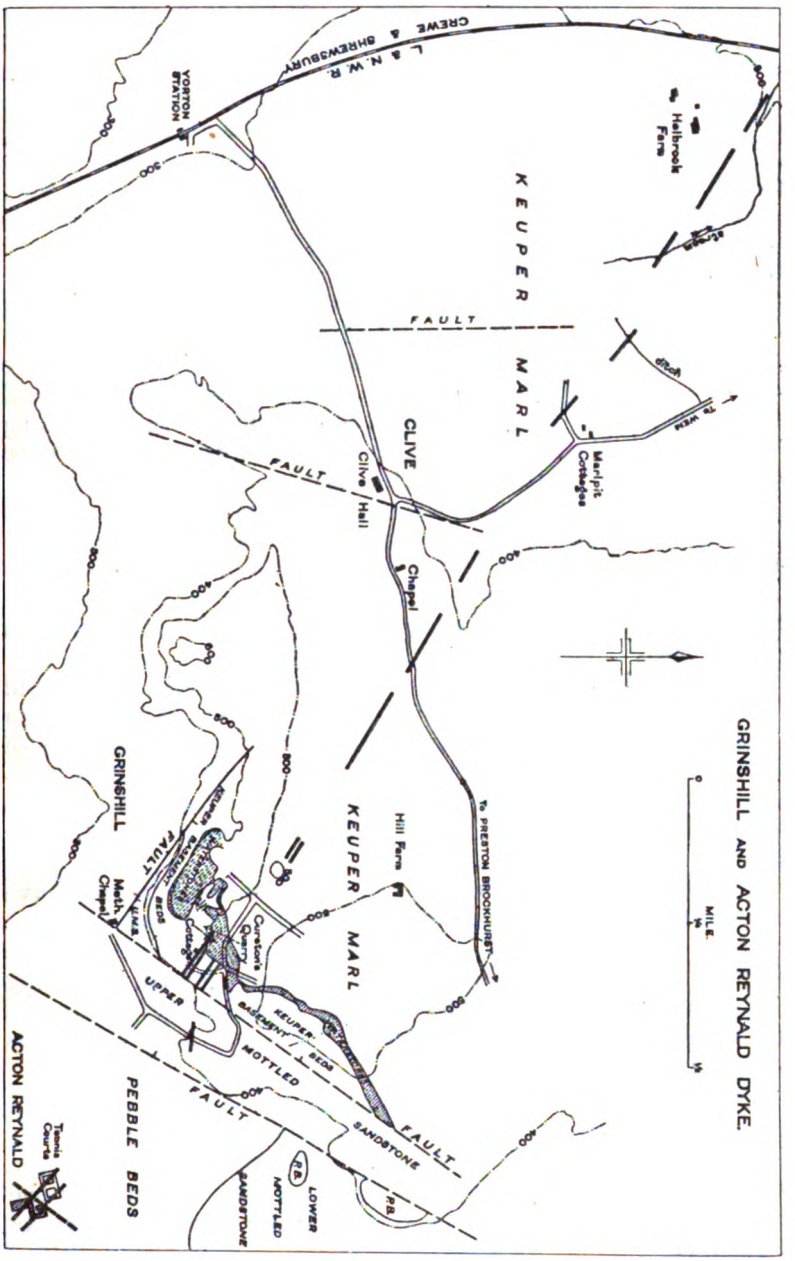

FIG. 6.—*Sketch-map showing the course of the Grinshill and Acton Reynald Dyke.*

were found 200 yards to the south-east of this point. The dyke is exposed about 250 yards further to the south-east in a small

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stream. It is here about two and a half feet wide with a strike S. 60° E. and has altered the Keuper Marl for a few inches on either side. About 10 yards downstream to the north a narrow branch vein is exposed.

The next exposure, about 250 yards east by south of the last, is not quite in the main line of the dyke, possibly due to shifting by a north and south fault for which there is evidence further south. The igneous rock is here seen in a ditch, cutting through Keuper Marl with thin sandstone bands.

About 100 yards down the lane west of Marlpit cottages there is a poor exposure from which fragments of the dyke rock and altered sandstone and marl were obtained.

A second fault seems to cut the dyke just east of the road from Clive to Wem. Beyond this the main direction is again indicated by fragments at a point 400 yards north-east of Clive Hall, and again 250 yards east by north of the Congregational Chapel where many large fragments were found in a hedge running north from the Preston Brockhurst road. Other fragments were met with 250 and 400 yards south-east of the last locality.

The dyke is seen apparently *in situ* 300 yards south by west of Hill Farm and seems to consist of two parallel branches differing somewhat in character. In the adjoining field to the east there is a slight rise in the ground on the line of the dyke which may be due to an expansion of the latter; at this point however there is no exposure.

The line of strike of the dyke crosses the crest of the hill overlooking Acton Reynald Park. Here the Keuper Marl is seen in the well-known Grinshill Quarries resting on about 20 feet of Waterstones or Flag Rock, at the base of which there is a well-defined loose sandy bed known as the " Esk Bed " which averages 9 inches in thickness and forms the upper limit of the Keuper Basement Beds or Grinshill Freestone.

In the Freestone the igneous material appears to have ascended along several more or less vertical and parallel fissures or joints as is indicated by exposures in the hillside. Four distinct branches, each about 2 feet wide, can be seen crossing an old cart track that descends the hill in a southerly direction through the woods from the corner of the old lane 600 yards south by east of Hill Farm.

The most southerly of these branches, when traced towards the north-west, passes through the coal shed of a cottage, along the base of a face of Freestone that forms the north-eastern boundary of the cottage garden and can be seen cutting the face of Freestone that forms the north-western boundary of the garden.

It is seen again in " Cureton's Quarry " 50 yards north-west of the cottage. This section is the best met with. The Freestone in the main quarry has been cut back to the junction with the igneous rock and the latter has been left forming the quarry wall. In one place, however, the quarrying operations

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have been carried further, the dyke rock has been removed, and a deep excavation made behind it. In the north-west face of this excavation the dyke can be seen curving down below the level of the floor of the main quarry, while above a small tongue or apophysis narrows upward into a joint in the sandstone.

In the south-eastern face of the main quarry two separate vertical branches of the dyke can be seen.

There appears to have been no movement of the rocks on either side of the dyke in any of these exposures as the " Esk Bed " is at practically the same level at all points in the quarry.

At the foot of the hill below the quarries an important fault running N. 35° E. appears to have affected the strike of the dyke as is indicated in the next exposure in the old lane 400 yards north-east of the Methodist Chapel, Grinshill. Here the dyke can be seen passing through the bright red sandstone of the Upper Mottled division of the Bunter with a strike N. 80° W. It is about 2 feet wide and has bleached the red sandstone for a distance of 18 inches to 2 feet on either side.

Between this point and Acton Reynald Park there is evidence of another fault running N. 30° E. and throwing down the Upper Mottled Sandstone on the north-west against the Pebble Beds of Acton Reynald Park.

In the Park no exposure of the dyke is now visible, but the rock has been seen in the sides of an old well in the courtyard of the house. This well was filled in in 1893, and new kitchens built over the spot. The dyke was also exposed, in the process of lowering the more westerly of the two tennis courts crossing the court diagonally from north-west to south-east.

From this information the direction of strike appears to be about south-east.

Large blocks of the rock from this locality were dumped near the engine house in the adjoining Apollo's Coppice, and specimens have been obtained from these.

No evidence relating to Murchison's parallel dyke or his larger intersecting dyke could be obtained.

All the evidence tends to show that the dyke is post-Triassic in age as it is intruded into and has altered the Keuper Marl and underlying divisions of the Keuper and Bunter.

The change in strike in the neighbourhood of the faults indicates that its intrusion may be earlier than the main faulting of the district.

Fourteen sections (12071–12084) of the Acton Reynald Dyke in different parts of its course have been prepared for microscopic examination and the following account is contributed by Dr. Flett :—

The rock is a decomposed porphyritic dolerite. Towards its margins the dyke is fine-grained with small porphyritic felspars in a micro-crystalline groundmass. These marginal specimens are sometimes vesicular and are always much decomposed. The central portions of the dyke are dark grey in colour with white porphyritic felspars, up to a quarter of an inch in length, scattered through the groundmass. Under

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the microscope none of the rocks proves to be in good preservation. The pyroxene is entirely replaced by secondary products and it is impossible to be certain whether olivine was originally present. Calcite, chlorite, kaolin and quartz are abundant; it is probable that all the quartz is secondary. The porphyritic felspars in the freshest rocks are labradorite, with complex twinning and a slight development of zonal structure. In some of the more decomposed slides these felspars are albitized. The felspars of the groundmass are also labradorite, where their characters can be determined. Iron-ores—magnetite and ilmenite—are frequent and leucoxene, pyrites and apatite are also common in the slides. The general characters of the rock indicate that it is a porphyritic dolerite which originally was not rich in olivine, and may have belonged to the tholeiite group.

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APPENDIX V

On a Boring at Bootle, near Liverpool

By D. A. Wray, M.Sc.

In 1914, a boring for water was made at Messrs. Bryant and May's Diamond Match Works, Bootle. The actual site is in Linacre Road, 300 yards south of Linacre Road station (Lancashire and Yorkshire Railway), and at a height of about 30 feet above O.D.

Maps.—One-inch New Series Ordnance, 83; Old Series Geological 90 S.E.; Six-inch, Lancashire 99 S.W. Latitude, 53° 27′ 55″. Longitude, 2° 59′ 55″.

The boring was made by Messrs. J. Thom & Co., Engineers, of Patricroft, near Manchester, to whom we are indebted for the record given below. It had been anticipated that under a thin covering of drift the Bunter Sandstones, so dependable as a source of underground water-supply in the country to the immediate south, would have been met with. Instead, however, under a rather abnormal thickness of drift, the Keuper Marls, hitherto unsuspected in this district, were met with and found to attain a thickness of 230 feet. The boring was ultimately carried to a depth of 383½ feet from the surface, and finished in the Lower Keuper Sandstone.

The borehole has a diameter of 7 inches, and is lined for 170 feet; its present yield is about 8,000 gallons of water per hour.

	Thickness. Ft.	in.	Depth. Ft.	in.
Glacial Drift, 77 ft. 8 ins. :—				
Clay and stones	25	0	25	0
Gravel and boulders	5	0	30	0
Clay	7	0	37	0
Gravel and boulders	6	0	43	0
Clay	3	0	46	0
Gravel and boulders	9	0	55	0
Clay	1	0	56	0
Gravel and large boulders	4	0	60	0
Gravel	4	0	64	0
Line of boulders and sand		8	64	8
Gravel	3	0	67	8
Boulders and gravel	10	0	77	8
Keuper Marl, 234 ft. :—				
Rubbly sandstone	1	6	79	2
Sandstone	1	0	80	2
Soft red marl	9	6	89	8
Sandstone	0	9	90	5
Soft marl	10	0	100	5
Sandstone	0	7	101	0
Soft sandy marl	5	0	106	0
Sandstone band	0	8	106	8
Soft red marl	10	0	116	8
Marl	5	0	121	8

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	Thickness. Ft.	in.	Depth. Ft.	in.
Keuper Marl—continued.				
Marl and sandstone plies	9	0	130	8
Red marl and sandstone plies	10	0	140	8
Red marl	7	0	147	8
Red marl and sandstone plies	8	0	155	8
Red and blue marl	4	0	159	8
Marl and sandstone plies	3	0	162	8
Mixed marl	9	0	171	8
Marl and sandstone plies	7	0	178	8
Red marl	6	0	184	8
Red marl and sandstone plies	6	0	190	8
Mixed marl	10	0	200	8
Red marl and sandstone plies	6	0	206	8
Mixed marl	3	0	209	8
Soft mixed marl	2	0	211	8
Red marl and sandstone plies	7	0	218	8
Red marl	5	0	223	8
Red marl and sandstone plies	10	0	233	8
Mixed marl	9	0	242	8
Red sandy marl	20	0	262	8
Mixed marl	8	0	270	8
Red marl and sandstone plies	20	0	290	8
Mixed marl	6	0	296	8
Red marl and sandstone plies	15	0	311	8
Keuper Sandstone (*or Waterstones*?), 71 ft. 10 ins.:—				
Sandstones	20	0	331	8
Mixed marl	3	0	334	8
Hard sandstone	10	0	344	8
Hard mixed marl	1	4	346	0
Hard sandstone	11	0	357	0
Hard red sandy marl	13	0	370	0
Soft sandstone	2	0	372	0
Hard sandstone	11	6	383	6

This record, combined with the additional data given below, which have been published since the last geological survey of this district, suggest that considerable modification is necessary in the boundaries shown on the Old Series Geological Map 90 S.E.

As long ago as 1884, T. M. Reade recorded the presence of Keuper Marl at Moorside, near Great Crosby,[1] about two miles to the north of the site of the present boring. Subsequently Keuper Marl was also met with in a boring for water at Cook's Lane, Great Crosby.[2] Several shallow borings were made in 1906 at the Battery, to the immediate south-west of Hightown station, and these again revealed the presence of Keuper Marl underlying the Boulder Clay and later deposits.[3] Still farther north, at Altcar, 2 miles east of Formby station, the Keuper Marl was found to attain a thickness of 971 feet[4] while trial borings made by the Lancashire and Yorkshire Railway Company, alongside

[1] *Geol. Mag.*, 1884, pp. 445–447.
[2] *Ibid.* 1901. p. 417.
[3] C. B. Travis. 'On some borings near Hightown' *Proc. Liverpool Geol. Assoc.*, 1908, pp. 11–13.
[4] G. H. Morton. 'Recent borings in the Red Marl, near Liverpool.' *Brit. Assoc. Report*, 1896, pp. 780–781.

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the railway at Altcar Rifle Range station, also showed the presence of Keuper Marl underlying the Glacial deposits.[1] From the foregoing records it seems highly probable that the glacial and later deposits of the Formby, Crosby, and Bootle coastal plain are underlain by Keuper Marl, and not Keuper and Bunter sandstone as is indicated on the Old Series map. It is also possible that the Keuper Marl revealed in the Linacre Road boring is separated from the Bunter sandstones seen at Fazakerley and Walton by the northerly continuation of the prominent north and south fault of Liverpool,[2] which separates the Keuper and Bunter formations throughout its course in the city.

[1] T. M. Reade. 'On some borings at Altcar made by the L. & Y. Rly. Co.,' *Proc. Liverpool Geol. Soc.*, 1900, vol. ix., pp. 359–369.

[2] *See* one-inch Geological Map (Old Series) 79 N.E., of which a new edition is now in progress.

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APPENDIX VI

The Zones of the Kimmeridge and Portland Rocks at Swindon

By C. P. Chatwin and J. Pringle

Attention has been drawn to the succession of beds at Swindon since the Survey acquired part of the collection of fossils formed by the late W. H. Hudleston. These fossils were in the possession of Dr. Catherine A. Raisin, and were presented by her to the Survey in December, 1920.

Various beds, exposed when the collection was made, are now inaccessible, but the fossils obtained from them have assumed importance on account of the development of the zonal classification of the Upper Jurassic rocks. In Hudleston's time the idea of narrow zonal division had not become generally adopted, but he collected carefully, bed by bed, around Swindon, and denoted the order of the strata by attaching to each specimen a label bearing such symbols as "B c," "D a," and "D c." The precise significance of these symbols was for a time a matter of conjecture only; and during the examination of the collection several questions arose which made it clear that a visit to the locality would be profitable. A brief visit was sufficient to enable the various horizons to be identified, but the work was helped considerably by excavations then being made in the cemetery and in the lower part of Messrs. Hill's brickyard. As a result, a zonal sequence has been identified from the base of the Kimmeridge Clay up to the highest beds of the Portland rocks in the district. To a great extent this sequence corresponds to the scheme proposed by Dr. H. Salfeld,[1] but the identification of an horizon temporarily exposed in the digging of graves in the cemetery as his zone of *Perisphinctes eastlecottensis* has led to certain modifications. At the time of Dr. Salfeld's work in the district (1912) there was no exposure of the beds from which the type of this zone-fossil came, although Hudleston had collected extensively from the horizon when it was to be seen in the railway-cutting of the Midland and South-Western Junction Railway to the west of Swindon Town Station.

The specimens on which Dr. Salfeld founded his new species came actually from an horizon much lower than that to which it it was assigned. This horizon is below the Swindon Clay and not above it, as stated (*op. cit.*, p. 430).

The following zonal scheme, established by combining the evidence of certain specimens in the Hudleston collection with that of fossils recorded by various geological writers and with observations made by ourselves, shows that Dr. Salfeld's zonal

[1] *Quart. Journ. Geol. Soc.*, vol. lxix,, 1913, pp. 423–432.

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classification of the Kimmeridge and Portland rocks (here emended) has complete representation in the district.

Zones.		Stratal Sequence.	Thickness. Ft.	in.	Hudleston's Designations.
		[Purbeck beds, resting on]			
Portland Series.	Perisphinctes giganteus & P. bononiensis	Hard white chalky limestone with *Lucina*, *Cerithium*, etc.	3	0	
		Seam of grey marl	0	2	
		White-weathering, compact limestone with small grains of quartz	1	6	
		Dark grey, clayey sand with shelly layers	1	3	
		Sands with Swindon Stone	25	0	B b
	P. pseudogigas & P. okusensis	Sandy limestone	4	6	B c
	P. gorei (Lydite-bed at base).	Sandy limestone (with derived *P. pallasianus* at base)	3	6	
Kimmeridge Series.	P. pallasianus.	Swindon Clay (Blue clay sandy at base)	14–20	0	
		Hard, greenish marl with lydites		8	C b
		Sands and clays with *Exogyra bruntrutana*	3–4		
	P. eastlecottensis (& P. pectinatus *auctt.*)	Green and red marly sandstones.	3–4		D a
		Grey and buff sands with doggers	30–40		D c
	Virgatites spp.	Dark-green sandy clay Dark bluish-grey clay			"Portland Clay."
	Gravesia zones.	Clay in Bazzard's (upper) pit.			
	Aulacostephanus zones	Oil-shales with clays in Bazzard's (middle) pit.			
	Rasenia zones	Clay at Swindon Wharf & Bazzard's (lower) pit.			
	Pictonia	Lower clay in Bazzard's (lower) pit (*fide* Salfeld)			

[*Note.*—The name *Perisphinctes* is not truly applicable to any of the above ammonities. It is used temporarily until the revision-work on these species is published.]

New information concerning the *eastlecottensis* zone proves that the upper part of the Kimmeridgian in this area is in part arenaceous. This is in accordance with the view expressed by

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H. B. Woodward, who stated[1] :—"There can be no question that the clay below the Portland Stone at Swindon is homotaxial with the Hartwell Clay, for although the Swindon Clay is not so fossiliferous as that at Hartwell, yet it has yielded some species, and the beds immediately below the Swindon Clay have yielded many fossils identical with those of the Hartwell Clay, as shown by the lists of Prof. Blake and Mr. Hudleston."

The sequence of Kimmeridge strata at Swindon affords instructive comparison with the succession in Dorset and Kent. In Dorset the clay-facies merges gradually upwards into marly sands—the so-called Portland Sands—which are surmounted by the cherty beds of the Portland Stone. In Kent there is no sandy facies at the top of the Kimmeridgian, but clay conditions continue right up to the base of the Portland Stone series.

The Kimmeridge Clay is at present poorly exposed near Swindon; portions of it can be seen only at two localities, namely, in certain parts of Turner's old clay-pits and in Messrs. Hill's brickyard. The basal clays are not exposed in the district in any natural sections, but the deep well made by the Great Western Railway Company, at the western end of their works, passed through the following :—

		Ft.	in.
	Made ground	8	0
Kimmeridge Clay (42 ft. 1 in.)	Bluish-grey clay, with Ammonites, &c.	42	0
	Pale-grey shelly limestone with *Ostrea deltoidea*		1
Corallian (22 ft.)	Grey and brown earthy limestone with patches of iron-shot grains		6
	Hard, brown, calcareous, muddy clay	2	0
	Bluish-grey shelly clay	19	6
	Limestones, &c.	—	

In the account of the boring from which we have obtained the above particulars of the beds, all of the clays down to the depth of 72 feet were regarded as belonging to the Kimmeridge Clay. It is likely, however, that the actual top of the Corallian was entered at the depth of 50 feet from the surface, since Dr. Salfeld has shown that the clay-facies extends downwards to the zone of *Perisphinctes decipiens*. We believe that the limestone with iron-shot grains should be regarded as the top of the Corallian, since the rock-specimens available show the matrix to be closely similar to the bed of iron-ore at Westbury. Moreover, Mr. E. T. Newton has recorded the occurrence in it of *Ammonites cordatus* var. *excavatus* (= *Amoeboceras serratum*). Our assignment of these beds to the Corallian is in conformity with the view of H. B. Woodward, who remarked that "when we compare the Swindon section with that at Highworth, about 6 miles to the north-east, we might be disposed to put more than we have included with the Corallian rocks at Swindon" (*op. cit.*, p. 119). Unfortunately, few fossils appear to have been preserved from the upper portion of the well.

[1] 'The Jurassic Rocks of Britain' (*Mem. Geol. Surv.*), vol. v., 1895, p. 223.

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Commencing with the lowest beds of the Kimmeridge Series we note that clays with *Pictonia* are recorded by Dr. Salfeld as being exposed in Turner's (Bazzard's) lower pit, now covered up. The presence of the next higher horizon—that of the Rasenia zones—at Swindon is proved by certain specimens collected by Hudleston from the wharf. In the brick and tile yards north of Old Swindon, H. B. Woodward states that he saw about 25 feet of the blue shaly clay, racy near the top, with septaria and selenite. Remains of *Ichthyosaurus*, *Cetiosaurus*, and *Omosaurus* have been obtained from these clays, and it is probable that these are from the same horizon—the Rasenia zones—as the saurian remains from Gillingham in Dorset.

Along the Midland and South-Western Junction Railway, to the south-west of North Lanes, a cutting (since grown over) showed brown and grey clays with septaria, yielding *Exogyra virgula* (Defr.) and *E. nana* (J. Sow.); these probably belong to the same zone. According to Dr. Salfeld, again, the leathery shales at the top of Turner's lower clay-pit contain *Aulacostephanus pseudomutabilis* (de Loriol) and *A. eudoxus* (d'Orbigny), which are characteristic of the higher Aulacostephanus zone. These shales are impure oil-shales, and are similar to the oil-shales found within the same zone at Broad Bench, in Kimmeridge Bay. Dr. Salfeld failed to find evidence of the Gravesia beds, which normally succeed this horizon, but a specimen in the Hudleston collection appears to fill the gap. Some of the higher beds, a short distance below the "Portland Sands," may still be seen in Turner's brickyard, and have yielded, according to Dr. Salfeld, *Virgatites miatschkoviensis* Vischn., *V. sosiae* Vischn., and *V. dorsoplanus* Vischn. These shells characterize the clays between the Yellow Ledge and the oil-shales known as "Kimmeridge Coal" (*Saccocoma* horizon) in Kimmeridge Bay.

In Messrs. Hill's brickyard, highly fossiliferous clays are worked at the present time, and these are shown by the ammonites to belong also to the Virgatites zone. The clays change gradually from a bluish-grey greasy clay through dark-green sandy clay to an uppermost bed of greenish-grey sandy clay, which weathers a tawny colour. In the bluish-grey clay *Protocardia morinica* (de Loriol), *Camptonectes morini* (de Loriol), *Lucina minuscula* Blake, and ammonites with virgatotome type of ribbing occur.

Careful comparison with specimens in the Hudleston collection leaves no doubt that the dark-green sandy clay is the horizon which Hudleston called the "Portland Clay," from which he obtained an extensive collection of lamellibranchs. The species that have been identified are closely similar to the Hartwell lamellibranch fauna, and include the following:—*Camptonectes morini* (de Loriol), *Grammatodon catalaunicus* (de Loriol), *Grammatodon* sp. nov., *Perna bouchardi* Oppel, *Cyprina implicata* de Loriol, *Modiola* cf. *tombecki* (de Loriol), *Protocardia morinica* (de Loriol), *Anatina* sp. nov., *Ostrea* cf. *expansa* J. Sowerby, *O. bononiae* Sauvage, *Modiola bononiensis* (de Loriol), *Astarte hartwellensis* J. de C. Sowerby, and *Syncyclonema nitescens* (Phillips). *Camptonectes*

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morini is particularly abundant, as is also the case at Hartwell; and the occurrence in both clays of the rare *Anatina* sp. nov. is notable. On the other hand, only one adult and two young specimens of *Astarte hartwellensis* were found in the Hudleston collection. *Trigonia pellati* Mun.-Chalmas, and *Astarte saemanni* de Loriol, which occur commonly at Hartwell appear to be absent in this clay at Swindon, but occur above in the sandy beds with *Perisphinctes eastlecottensis*. The prolific lamellibranch fauna characteristic of the Hartwell Clay at Hartwell has its origin therefore in the Virgatites zone.

The clays pass gradually upwards into " sands with doggers," forming what has hitherto been known as the Lower Portland Sand. The junction may still be seen in the southern end of Turner's old brick pit. The sands are poorly fossiliferous except in the uppermost beds, where green marly sandstones with lydite pebbles yield a rich lamellibranch fauna representing many of the Hartwell species. Low down in the series a few fossils have been found in the nodules of fine-grained grey sandstone; two specimens in the Hudleston collection (labelled D c) have been identified as *Syncyclonema nitescens* (Phillips) and *Thracia incerta* (Thurmann).

The fine series of fossils from the upper beds (labelled D a by Hudleston) were collected during the construction of the Swindon and South-Western Junction Railway. These upper beds were at one time (1887) well exposed in the road-cutting below Victoria Street, and the section was recorded by H. B. Woodward (*op. cit.*, p. 214). A similar section was visible in May 1921 in a disused clay-pit south of Stafford Street; this pit has now been filled in, but from time to time the beds are exposed when graves are dug in the old cemetery, in the slope overlooking Clifton Street. Many fine uncrushed ammonites have been found in the material thrown out in grave-digging; these include *Perisphinctes eastlecottensis* Salfeld, *P. rotundus* (J. Sowerby) *P. pectinatus* auctt., and a number of large fragments of ammonites referable to *Pseudovirgatites*. Examination of the type-specimen of *P. eastlecottensis* Salfeld in the British Museum shows that this shell was undoubtedly obtained from this horizon, and that Dr. Salfeld was mistaken in referring it to the lydite-bed above the Swindon Clay. The matrix, which still adheres to part of the specimen, contains examples of the characteristic lamellibranchs of the bed.

Mr. S. S. Buckman, who has examined the type of *Ammonites pectinatus* Phillips in the University Museum at Oxford, informs us that the shells from Swindon that have been thus identified are not related to Phillips's type-form, but probably represent an undescribed species. Similar finely-ribbed shells are found in the oil-shale horizon of Kimmeridge and Corton, and those from this horizon in Lincolnshire have been referred to *A. pectinatus* by Blake. A comparison shows a very close resemblance in external morphology, but unfortunately no traces of sutures

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are to be seen in specimens from the oil-shales. The delicate ribs are crowded, strongly inclined forwards, and bifurcate nearer the umbilicus than the middle of the flank, although inconstancy in this feature may be observed in individual specimens. Occasionally single ribs are interposed, and in adult shells the periphery becomes broad and distinctly flattened. The fragments referred to *Pseudovirgatites* show a close resemblance to the large ammonites which characterise the oil-shale horizon at Corton, where the shales have been mined. The identity of these forms is difficult to establish on account of varying conditions of preservation; consequently, unless phylogeny can be traced, there remains the possibility (which we consider remote) of similar external morphology being repeated by different stocks at more than one horizon. The sands and clays overlying this richly fossiliferous horizon at Swindon are characterized by the abundance of *Exogyra bruntrutana* Thurmann, but no ammonites appear to have been recorded from them.

The overlying Swindon Clay is a blue clay, weathering brown, more sandy in the lower portion and having at its base a hard, green sandy marl with lydite pebbles (C b of Hudleston). Except for the occasional opening of graves in the cemetery, the lower beds of this clay are no longer exposed in the district. The upper limit is seen immediately beneath the floor at the eastern end of the Okus Quarry. Although H. B. Woodward correlated the Swindon Clay with the Hartwell Clay, there was at that time no ammonite-evidence available; during recent visits, however, we were fortunate enough to obtain several specimens, which, together with some collected by Mr. C. H. Gore, show that the Swindon Clay, like the Hartwell Clay, is in the zone of *Perisphinctes pallasianus*. Further evidence of the presence of the zonal ammonites is to be found in the origin of the numerous fragments of *P. pallasianus* included in the lydite-bed which forms the base of the local Portland stone series. These were obviously derived from the Swindon Clay.

With the recognition of this clay as belonging to the *pallasianus* zone, we come to the upper limit of the Kimmeridge series of Swindon. An abrupt change in lithology marks the upper limit of the Swindon Clay and appears to denote that some movement had taken place within the area of deposition. This is borne out by the presence of many lydite pebbles and numerous derived fossils in the succeeding bed, a bluish marly limestone. The extent of the non-sequence may be gauged by the fact that in Kimmeridge Bay nearly 200 feet of clays and sands lie between the upper part of the zone of *P. pallasianus* and the zone of *P. gorei*. The marly limestone, one foot in thickness, is seen in contact with the Swindon Clay only at the eastern end of the Okus Quarry, and its upper edge crops out at the side of the lane in the western end of Pembroke Street.

The Portland rocks which follow this lydite-bed are well exposed in the Okus Quarry and in the old quarries in the Town

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Gardens. The lithological succession is well known from the sections published by H. B. Woodward and other writers, and a palæontological sequence was established by Dr. Salfeld in 1912. He places the band of bluish-grey limestone (3 ft. 6 in.) overlying the lydite-bed in the zone of *Perisphinctes gorei*, and observes that the boundary drawn between the Portland Sands and the Portland Oolite in the Isle of Purbeck would fall above the *gorei* zone at Swindon. The highly fossiliferous sandy limestone known as the "cockly bed" is referred to the zone of *Perisphinctes pseudogigas*, from which he describes a new ammonite as *P. okusensis*. The overlying sands with Swindon Stone are succeeded in the old quarries in the Town Gardens by chalky limestones, and have been referred by Dr. Salfeld to the zones of *Perisphinctes giganteus* and *P. bononiensis*, though up to the present these species have not been recorded from Swindon.

Acknowledgment should here be made of the assistance received from Mr. C. H. Gore, Hon. Curator of the Swindon Museum, who kindly placed the results of his own collection at our disposal.

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APPENDIX VII

The Subdivisions of the Red Rocks formerly classed as Permian in South Staffordshire and the Neighbouring Counties

By Talbot H. Whitehead, M.Sc., A.R.C.Sc.

The red sandstones and marls overlying the Halesowen Sandstones of South Staffordshire were placed by Jukes[1] in the Permian System. Howell[2] adopted the same course with the similar rocks overlying the beds recognised by him as Coal Measures in Warwickshire. These red rocks were later described by Hull,[3] in greater detail and over a wider area, under the term 'Lower Permian, Salopian Type.'

Mr. Charles Ketley[4] in 1875 and Messrs. Meachem and Insley[5] in 1886 expressed the opinion that part at least of the rocks classed by the Geological Survey as Permian belonged to the Coal Measures. This view was confirmed, on palæobotanical grounds, by Dr. Kidston's paper of 1888.[6]

Mr. Cantrill,[7] in 1895, pointed out the close relationship between the Lower Permian of Salopian Type and the Upper Coal Measures. He concluded that the whole of the former should also be regarded as Upper Coal Measures, and described as Coal Measure Passage Beds.

During the re-survey of the North Staffordshire coalfield it was found that rocks forming part of Hull's Salopian Permian were conformable with the Coal Measures, with which they had certain characters in common, and that these rocks contained Coal Measure fossils. They were, accordingly, relegated to the Upper Coal Measures under the name Keele Sandstone Series.[8]

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[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, chap. iv.

[2] 'The Warwickshire Coal-Field' (*Mem. Geol Surv.*), 1859, chap. iii.

[3] 'Triassic and Permian Rocks of the Midland Counties' (*Mem. Geol. Surv.*), 1869, p. 12.

[4] Ketley, C. 'The Search for Coal under the "Red Rocks" of the South Staffordshire Coal-Field.' *Geol. Mag.*, 1875, p. 197.

[5] Meachem, F. G., and H. Insley. 'Notes on the Rocks between the Thick Coal and the Trias North of Birmingham and the Old South Staffordshire Coalfield.' *Rep. Brit. Assoc.* for 1886 (1887), p. 626.

[6] R. Kidston. 'On the Fossil Flora of the Staffordshire Coal Fields.' Part I. *Trans. Roy. Soc. Edin.*, vol. xxxv, 1888, p. 317.

[7] T. C. Cantrill. 'On the Occurrence of *Spirorbis*-limestone and Thin Coals in the so-called Permian Rocks of Wyre Forest, etc.' *Quart. Journ. Geol. Soc.*, vol. li, 1895, p. 528.

[8] 'Summary of Progress' for 1898 (*Mem. Geol. Surv.*), 1899, pp. 122, 123. It had already been suggested by Mr. John Ward that part of the rocks in question were of Coal Measure age: 'The Geological Features of the North Staffordshire Coal Fields.' *Trans. N. Staff. Inst. Min. Eng.*, vol. x, pt. 5, 1890, p. 14.

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In his paper of 1899 Mr. W. W. King[1] adopted the following classification of the 'Permian' rocks of the region with which he dealt :—

(3). An upper group of marls, with included breccias.
(2). A middle group of calcareous sandstones, locally conglomeratic, interbedded with marls and sandstones.
(1). A lower group of marls and sandstones.

This classification differs from that of Hull only in relegating the breccias to the upper instead of the middle group. This modification appears justified by Mr. King's discovery that bands of breccia occur, interstratified with marls and sandstones, above the 'trappoid breccia' that forms the base of his upper group[2]; and that the breccias pass laterally as well as vertically into marls.[3]

In 1901 Dr. Gibson[4] showed that the sequence of the Upper Coal Measures adopted in North Staffordshire could be recognised in other localities, including South Staffordshire, where "the olive-coloured sandstones and shales . . . of Illey Brook, which lie at the top of the Halesowen Series . . . are succeeded by red sandstones and marls identical with the Keele Series." The red sandstones and marls referred to belong to the lowest division of Hull's Lower (Salopian) Permian.

During the re-survey of the Warwickshire coalfield it was found that the beds identified with the Halesowen Sandstones of South Staffordshire passed conformably upwards into red marls and sandstones corresponding approximately with the Keele Beds of North Staffordshire.[5]

Mr. Cunnington, as the result of further examination of these red sandstones and marls in the central portion of the Warwickshire Coalfield, found that the following sequence could be made out :—

(3). Upper Group.—Red marls and soft red sandstones.
(2). Middle Group.—Hard red sandstones with calcareous conglomerates.
(1). Lower (Keele) Group.—Red marls and sandstones with three Spirorbis limestones.

Of this sequence only the lowest division could be definitely correlated with the Keele Group of North Staffordshire.[6] A similar division into three groups was found applicable at the southern end of the coalfield.[7]

In the Survey memoir on the Coventry Sheet (169) the beds comprised in groups (2) and (3) of the above sequence have been

[1] W. W. King. 'The Permian Conglomerates of the Lower Severn Basin.' *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 100.
[2] W. W. King, *op. cit.*, p. 102.
[3] Personal communication from Mr. King.
[4] W. Gibson. 'On the Character of the Upper Coal-Measures of North Staffordshire, Denbighshire, South Staffordshire, and Nottinghamshire' *Quart. Journ. Geol. Soc.*, vol. lvii, 1901, p. 262.
[5] 'Summary of Progress' for 1911 (*Mem. Geol. Surv.*), 1912, p. 25.
[6] *Ibid.* for 1913, 1914, p. 22.
[7] *Ibid.* for 1914, 1915, p. 19.

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described under the local name Corley Beds, which name also appears on the corresponding one-inch and six-inch maps.

Beds including calcareous conglomerates similar to those of the Warwickshire Coalfield were mapped in the area between the Warwickshire and South Staffordshire Coalfields, and along the borders of the northern portion of the latter.[1]

Certain outcrops of these rocks were found to be continuous with those of Hamstead, described by Mr. Hardaker.[2] The name Hamstead Beds, a modification of that author's local term Hamstead Quarry Series, was accordingly adopted and used, in the Lichfield Memoir, to cover "the red beds with conglomerates into which the Keele Group graduates upwards."[3] Mr. Hardaker[4] correlated his Hamstead Quarry Series in part with the Middle Permian and in part with the Upper Permian of Mr. King. If this correlation be accepted it follows that the term Hamstead Beds, as used in the Lichfield Memoir, includes by implication the Middle Permian, and part at least of the Upper Permian, of the latter author's classification.

In any case it seems convenient to use a common term to cover all the rocks belonging to the Middle and Upper divisions of the 'Permian' (of Hull and of King). The use for this purpose, and indeed in anything more than a strictly local sense, of the name Hamstead Beds is undesirable, as that name is already current for certain strata of Oligocene age. It is proposed, therefore, to adopt the name Enville Beds suggested (in the form Enville Series) by Dr. E. A. Newell Arber[5] in 1916.

The Enville Beds may, then, be defined as the equivalent of the Middle Series (B 2) and the Upper Series (B 1) of the Lower Permian of Salopian Type of Hull,[6] and of the Middle Permian and Upper Permian of Mr. King.[7] They comprise a lower Calcareous Conglomerate Group and an upper Breccia Group.[8]

The Calcareous Conglomerate Group consists of calcareous sandstones with lenticular calcareous conglomerates, and subordinate red marls and non-calcareous sandstones.

The Breccia Group consists of red marls with subordinate sandstones, and with breccias in the lower portion. These breccias may be thick and coarse as on the Clent Hills, or compara-

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[1] 'Geology of the Country around Lichfield' (*Mem. Geol. Surv.*), 1919, pp. 59–63, 117–121.

[2] W. H. Hardaker. 'On the Discovery of a Fossil-bearing Horizon in the 'Permian' Rocks of Hamstead Quarries, near Birmingham.' *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, p. 639.

[3] 'Geology of the Country around Lichfield' (*Mem. Geol. Surv.*), 1919, p. 4. The name 'Hamstead Beds' was, however, first published in the 'Summary of Progress' for 1915 (*Mem. Geol. Surv.*), 1916, p. 8.

[4] *Op. cit.*, p. 654.

[5] 'The Structure of the South Staffordshire Coalfield.' *Trans. Inst. Min. Eng.*, vol. lii, 1916, p. 38.

[6] *Op. cit.*, p. 13.

[7] *Op. cit.*, p. 100.

[8] The names Romsley Group and Clent Group were proposed for these two groups respectively by Dr. Arber, *op. cit.*, pp. 39, 40.

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tively thin and fine as at Gatacre and near Sedgley.[1] They may even be absent, as in the Warwickshire Coalfield, to which district it would perhaps be safer to defer the application of these subdivisions of the Enville Beds.

In the Calcareous Conglomerate Group the calcareous sandstones show over a wide area a tendency to occur in three bands separated by marls and non-calcareous sandstones. The conglomerates come in sporadically in the calcareous sandstones. These conglomerates are characterised by pebbles of limestone (Carboniferous and Silurian) and of red and yellow chert. The matrix is usually highly calcareous. The characteristic pebbles may occur scattered, so as to form a pebbly sandstone, or even isolated in the sandstones at some distance from an actual conglomerate. These calcareous conglomerates and pebbly sandstones are distinct from the 'pellet rocks' and conglomeratic cornstones which occur also in the Keele Beds; though it appears that the calcareous bands of the Enville Beds may in certain localities be represented by beds of the cornstone type.[2]

The calcareous sandstones are themselves lenticular, but are very much more persistent than the conglomerates, and have a marked tendency to recur on what is apparently the same horizon over a wide area. The base of the Enville Beds is placed at the base of the lowest of the calcareous sandstones associated with the calcareous conglomerates, and, as thus defined, appears usually to lie at from 700 to 900 feet above the base of the Keele Beds.

The Keele and Enville Beds together seem to constitute a generally conformable series, though there may occur local non-sequences as, for example, at the base of the 'trappoid breccia.'

It might, perhaps, be considered that the Breccia Group is of sufficient importance to be made a major subdivision of the "Permian" rocks equal in value to the Keele Beds. This would require that the Calcareous Conglomerate Group be made a third co-equal subdivision. This course would, in fact, amount to the adoption of Mr. King's classification (which is a modification of Hull's), the names only being altered. It may be pointed out, on the other hand, that the Breccia Group derives its importance chiefly from the interest excited by the Clent 'trappoid breccia.' This formation may, however, be regarded as a special local development in a series that is predominantly, and over its widest geographical extent, a marl group with subordinate sandstones and breccias.

Considering the 'Permian' rocks of South Staffordshire and the neighbouring counties as a whole, they consist of a series of red sandstones and marls, interrupted, at about the middle,

[1] *See* W. W. King, *op. cit.*, p. 105, and the present 'Summary', p. 32.

[2] *See* W. W. King, *op. cit.*, p. 111, and 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, p. 15.

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by the development of coarse sediments (conglomerates of special type, and breccias). In the absence of any well-defined plane of unconformity, the best major line of subdivision appears therefore to be at the place where these coarse sediments come in. Further, as already pointed out, the detailed correlation of the 'Permian' beds in Warwickshire with those in South Staffordshire is rendered uncertain by the absence of breccias in the former. It appears, however, that a twofold division into Keele and Enville Beds, with the correlations that this implies, can be safely adopted for the Warwickshire beds.

With regard to the geological age of the rocks formerly called Permian in South Staffordshire and the neighbouring counties, we have seen (p. 28) that the view has long been held that part at least of them belongs to the Coal Measures.

The Keele Beds are now, indeed, placed in the Coal Measures by general consent, though their exact correlation is still a subject of dispute.[1]

In the case of the Enville Beds the position is one of even greater uncertainty. Mr. Hardaker[2] obtained from beds belonging to the Calcareous Conglomerate subdivision of the group certain fossils that he considered established the Permian age of the rocks in question. This contention was disputed by Dr. Newell Arber.[3] The matter should, perhaps, be regarded as still *sub judice*; but in the meanwhile, in view of their apparently conformable relations with the beds below, it is convenient to place the Enville Beds provisionally with the Coal Measures.

In conclusion, the classification of the rocks formerly called Permian in South Staffordshire and the neighbouring counties, adopted by the Geological Survey, may be tabulated as follows :—

[Lower (Salopian) Permian of Hull.]	? Upper Coal Measures. Enville Beds (Corley Beds of Warwickshire).	Breccia Group. Calcareous Conglomerate Group.
	Upper Coal Measures. Keele Beds.	

[1] *See* (amongst other papers) R. Kidston 'On the Divisions and Correlation of the Upper Portion of the Coal-Measures, etc.' *Quart. Journ. Geol. Soc.*, vol. lxi, 1905, p. 308.

R. Kidston 'On the Fossil Flora of the Staffordshire Coal Fields.' Part III., *Trans. Roy. Soc. Edin.*, vol. l, 1914, p. 74.

E. A. Newell Arber. 'The Structure of the South Staffordshire Coalfield.' *Trans. Inst. Min. Eng.*, vol. lii, 1916, p. 42.

[2] *Op. cit.*, pp. 655–81.

[3] *Op. cit.*, p. 40.

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APPENDIX VIII

Determination of Iron in Ores and Silicate Rocks.

By F. R. Ennos, B.A. (Cantab.), B.Sc., A.I.C.,
and R. Sutcliffe, M.A. (Oxon), A.I.C.

In a communication published in the *Journal of the American Chemical Society* (1921, XLIII., 1560–1568), G. E. F. Lundell and H. B. Knowles point out some errors, and their causes, in the determination of iron in silicate rock analysis (W. F. Hillebrand, *The Analysis of Silicate and Carbonate Rocks*, Bull. 700 U.S. Geol. Survey, 1919, p. 119). Reduction of the ferric solution by hydrogen sulphide and titration with potassium permanganate, is stated to result in a positive error, which may amount to 0·5 per cent. when the concentration of acid present is low. It is believed by Lundell and Knowles that this is due to the formation, during reduction, of polythionic acids which can be oxidised by permanganate.

The following modification of the usual method is alleged by these authors to minimise the error. The cold solution, of volume 100 ccs., and containing 2·5 per cent. by volume of sulphuric acid, is saturated with hydrogen sulphide for thirty minutes, and then, raised to boiling point during a period of fifteen minutes, with continued passage of the gas. After filtration, the liquid is again saturated with hydrogen sulphide for ten minutes. 15 ccs. of 1 : 1 sulphuric acid are now added, and the liquid boiled down to 50 ccs. in a current of carbon-dioxide, diluted to 200 ccs. with cold water and titrated with permanganate.

Another process, recommended by them for more accurate work, may be summarised thus :—

Saturation of the acid solution by hydrogen sulphide.
Filtration.
Boiling out hydrogen sulphide.
Oxidation by 10 per cent. potassium permanganate solution.
Reduction with sulphur dioxide gas in slightly acid solution.
Boiling out sulphur dioxide in an atmosphere of carbon dioxide.
Increase of acid concentration.
Titration.

H. D. Newton (*Chemical News*, 1908, XCVII, 218) suggests the reduction of iron by titanous sulphate, oxidation of the excess of the latter by bismuth oxide, filtration from the excess of bismuth oxide, and titration with permanganate solution. This method is open to the objection that the platinum in the solution is not recovered and weighed, this being important in accurate work (Hillebrand, *op. cit.*, p. 119, Note 2).

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Previous to the publication of the work of Lundell and Knowles, we had adopted in this department, after careful examination, the use of standardised titanous chloride solution for the iron titration, as this method has been found to be accurate and speedy (E. Knecht and E. Hibbert, "*New Reduction Methods in Volumetric Analysis*"). This reagent has the advantage in general use that it may be employed with an internal indicator (ctr. potassium dichromate) for the determination of iron in either hydrochloric or sulphuric acid solution.

For the analysis of iron ores after extraction with hydrochloric acid (in which method of opening up aluminous minerals are not appreciably dissolved), a satisfactory process to adopt is that recommended by Knecht and Hibbert :—

> The iron in solution having been oxidised to the ferric state by the addition of hydrogen peroxide, and the excess of this reagent destroyed by making the solution slightly alkaline with ammonia and boiling for a few minutes, the ferric hydroxide is dissolved by adding an excess of concentrated hydrochloric acid; 5 ccs. of 20 per cent. ammonium thiocyanate are then added to the liquid after it has been cooled, and the standard titanous chloride run in until the colour is destroyed. If ammonium thiocyanate is used as an internal indicator, it gives the best results when present in large excess, and when the solution is strongly acid.

Organic indicators, including methylene blue ('Microscopic Reagent' and 'Medicinal') have been tried, but we do not recommend their adoption, as the end-points are not sufficiently sharp.[1] For iron titrations ammonium thiocyanate is satisfactory in the presence of hydrochloric acid.

Difficulties occur when dealing with the iron, alumina, titanium and phosphate solution, obtained in the ordinary course of rock analysis.

Firstly, under these circumstances, alumina is often present in large amount, and, when the liquid has been made alkaline and boiled to destroy the excess of hydrogen peroxide after oxidation of the iron, the aluminium hydroxide is rendered somewhat insoluble in acids. This insoluble alumina prevents a notable proportion of iron from being determined by titration.

Secondly, the pyrosulphate fusion of the weighed oxides of the aluminium group involves an unavoidable addition of platinum through corrosion of the crucible; and, as platinum salts have been found to be easily reducible by titanous chloride, and also to give a very strong reddish-brown colour with thiocyanate solutions, an uncertain amount of platinum will cause error in the iron determination.

[1] Some experimental work in hand points to the possibility of obtaining one of these indicators in a more suitable form, the change of colour being even clearer than is the case with ammonium thiocyanate.

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To obviate these difficulties we have devised the following method for the estimation of iron in silicate rocks :—

> The titanium is determined colorimetrically in the solution of the pyrosulphate melt before the usual evaporation to small bulk; the platinum has been found not to interfere with this determination. The solution is then evaporated to about 100 ccs., and the excess of hydrogen peroxide destroyed by adding to the hot liquid nearly enough sulphurous acid to discharge the colour. The solution is saturated with hydrogen sulphide at a temperature of about 90° C.,[1] and then, with a current of the gas passing, heated to boiling point. The sulphur and platinum sulphide precipitate, having been coagulated by boiling for a few minutes, the hydrogen sulphide current is stopped while the liquid is still boiling, and, after hot filtration and washing with very dilute sulphuric acid, the filtrate is cooled and oxidised with dilute permanganate solution until it is faintly pink; 10 ccs. of concentrated hydrochloric acid and the indicator are then added, and the solution titrated with titanous chloride.

This method, besides being more rapid than those suggested by Lundell and Knowles, has been found to give results quite accurate within the limits of experimental error. It has, in addition, these advantages; thionic acids, if formed during the reduction, are completely destroyed by the permanganate; alumina remains in solution throughout the process and so does not entangle any iron; platinum is completely removed in a weighable form; and oxidation by permanganate ensures that the iron is all in the ferric state before the final titration with titanous chloride.

[1] U. Antony and A. Lucchesi, *Gazzetta Chemica Italiana*, Anno XXVI, 1896, I, 211.

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